THE BOOK WAS DRENCHED

REPORT

OF THE

FORTY-SECOND MEETING

OF THE

BRITISH ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE;

HELD AT

BRIGHTON IN AUGUST 1872.

LONDON:
JOHN MURRAY, ALBEMARLE STREET.
1873.

PRINTED BY

TAYLOR AND FRANCIS, RED LION COURT, FLEET STREET.

ALERE FLAMMAM.

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ERRATA IN REPORT FOR 1871.

In Mr. Peacock's paper, p. 240 (Trans. of Sections):—

In second paragraph, line 2, *dele* and.

In line 5 of same paragraph, *for* 8 *read* 2.

ERRATA IN THE PRESENT VOLUME.

Page 352 (Reports), line 8 from bottom, *for* $J_c(v_1 - \frac{1}{2}m_\lambda\pi + \frac{1}{2}\delta_\lambda i \ldots)$ *read* $J_c(v_1 - m_1\pi + \delta_1 i \ldots)$.

„ 108 (Trans. of Sections), line 27, for *radiatus* read *radicans*.

OBJECTS AND RULES

OF

THE ASSOCIATION.

OBJECTS.

THE ASSOCIATION contemplates no interference with the ground occupied by other institutions. Its objects are:—To give a stronger impulse and a more systematic direction to scientific inquiry,—to promote the intercourse of those who cultivate Science in different parts of the British Empire, with one another and with foreign philosophers,—to obtain a more general attention to the objects of Science, and a removal of any disadvantages of a public kind which impede its progress.

RULES.

Admission of Members and Associates.

All persons who have attended the first Meeting shall be entitled to become Members of the Association, upon subscribing an obligation to conform to its Rules.

The Fellows and Members of Chartered Literary and Philosophical Societies publishing Transactions, in the British Empire, shall be entitled, in like manner, to become Members of the Association.

The Officers and Members of the Councils, or Managing Committees, of Philosophical Institutions shall be entitled, in like manner, to become Members of the Association.

All Members of a Philosophical Institution recommended by its Council or Managing Committee shall be entitled, in like manner, to become Members of the Association.

Persons not belonging to such Institutions shall be elected by the General Committee or Council, to become Life Members of the Association, Annual Subscribers, or Associates for the year, subject to the approval of a General Meeting.

Compositions, Subscriptions, and Privileges.

LIFE MEMBERS shall pay, on admission, the sum of Ten Pounds. They shall receive *gratuitously* the Reports of the Association which may be pub-

lished after the date of such payment. They are eligible to all the offices of the Association.

ANNUAL SUBSCRIBERS shall pay, on admission, the sum of Two Pounds, and in each following year the sum of One Pound. They shall receive *gratuitously* the Reports of the Association for the year of their admission and for the years in which they continue to pay *without intermission* their Annual Subscription. By omitting to pay this Subscription in any particular year, Members of this class (Annual Subscribers) *lose for that and all future years* the privilege of receiving the volumes of the Association *gratis*: but they may resume their Membership and other privileges at any subsequent Meeting of the Association, paying on each such occasion the sum of One Pound. They are eligible to all the Offices of the Association.

ASSOCIATES for the year shall pay on admission the sum of One Pound. They shall not receive *gratuitously* the Reports of the Association, nor be eligible to serve on Committees, or to hold any office.

The Association consists of the following classes:—

1. Life Members admitted from 1831 to 1845 inclusive, who have paid on admission Five Pounds as a composition.

2. Life Members who in 1846, or in subsequent years, have paid on admission Ten Pounds as a composition.

3. Annual Members admitted from 1831 to 1839 inclusive, subject to the payment of One Pound annually. [May resume their Membership after intermission of Annual Payment.]

4. Annual Members admitted in any year since 1839, subject to the payment of Two Pounds for the first year, and One Pound in each following year. [May resume their Membership after intermission of Annual Payment.]

5. Associates for the year, subject to the payment of One Pound.

6. Corresponding Members nominated by the Council.

And the Members and Associates will be entitled to receive the annual volume of Reports, *gratis*, or to *purchase* it at reduced (or Members') price, according to the following specification, viz.:—

1. *Gratis*.—Old Life Members who have paid Five Pounds as a composition for Annual Payments, and previous to 1845 a further sum of Two Pounds as a Book Subscription, or, since 1845, a further sum of Five Pounds.

   New Life Members who have paid Ten Pounds as a composition.

   Annual Members who have not intermitted their Annual Subscription.

2. *At reduced or Members' Prices*, viz. two thirds of the Publication Price.—Old Life Members who have paid Five Pounds as a composition for Annual Payments, but no further sum as a Book Subscription.

   Annual Members who have intermitted their Annual Subscription.

   Associates for the year. [Privilege confined to the volume for that year only.]

3. Members may purchase (for the purpose of completing their sets) any of the first seventeen volumes of Transactions of the Association, *and of which more than* 100 *copies remain*, at one third of the Publication Price. Application to be made at the Office of the Association, 22 Albemarle Street, London, W.

Volumes not claimed within two years of the date of publication can only be issued by direction of the Council.

Subscriptions shall be received by the Treasurer or Secretaries.

Meetings.

The Association shall meet annually, for one week, or longer. The place of each Meeting shall be appointed by the General Committee two years in advance; and the Arrangements for it shall be entrusted to the Officers of the Association.

General Committee.

The General Committee shall sit during the week of the Meeting, or longer, to transact the business of the Association. It shall consist of the following persons:—

CLASS A. PERMANENT MEMBERS.

1. Members of the Council, Presidents of the Association, and Presidents of Sections for the present and preceding years, with Authors of Reports in the Transactions of the Association.

2. Members who by the publication of Works or Papers have furthered the advancement of those subjects which are taken into consideration at the Sectional Meetings of the Association. *With a view of submitting new claims under this Rule to the decision of the Council, they must be sent to the Assistant General Secretary at least one month before the Meeting of the Association. The decision of the Council on the claims of any Member of the Association to be placed on the list of the General Committee to be final.*

CLASS B. TEMPORARY MEMBERS.

1. Presidents for the time being of any Scientific Societies publishing Transactions or, in his absence, a delegate representing him. *Claims under this Rule to be sent to the Assistant General Secretary before the opening of the Meeting.*

2. Office-bearers for the time being, or delegates, altogether not exceeding three, from Scientific Institutions established in the place of Meeting. *Claims under this Rule to be approved by the Local Secretaries before the opening of the Meeting.*

3. Foreigners and other individuals whose assistance is desired, and who are specially nominated in writing, for the Meeting of the year, by the President and General Secretaries.

4. Vice-Presidents and Secretaries of Sections.

Organizing Sectional Committees.*

The Presidents, Vice-Presidents, and Secretaries of the several Sections are nominated by the Council, and have power to act until their names are submitted to the General Committee for election.

From the time of their nomination they constitute Organizing Committees for the purpose of obtaining information upon the Memoirs and Reports likely to be submitted to the Sections†, and of preparing Reports thereon,

* Passed by the General Committee, Edinburgh, 1871.

† *Notice to Contributors of Memoirs.*—Authors are reminded that, under an arrangement dating from 1871, the acceptance of Memoirs, and the days on which they are to be

and on the order in which it is desirable that they should be read, to be presented to the Committees of the Sections at their first Meeting.

An Organizing Committee may also hold such preliminary Meetings as the President of the Committee thinks expedient, but shall, under any circumstances, meet on the first Wednesday of the Annual Meeting, at 11 A.M., to settle the terms of their Report, after which their functions as an Organizing Committee shall cease.

Constitution of the Sectional Committees.*

On the first day of the Annual Meeting, the President, Vice-Presidents, and Secretaries of each Section having been appointed by the General Committee, these Officers, and those previous Presidents and Vice-Presidents of the Section who may desire to attend, are to meet, at 2 P.M., in their Committee Rooms, and enlarge the Sectional Committees by selecting individuals from among the Members (not Associates) present at the Meeting whose assistance they may particularly desire. The Sectional Committees thus constituted shall have power to add to their number from day to day.

The List thus formed is to be entered daily in the Sectional Minute-Book, and a copy forwarded without delay to the Printer, who is charged with publishing the same before 8 A.M. on the next day, in the Journal of the Sectional Proceedings.

Business of the Sectional Committees.

Committee Meetings are to be held on the Wednesday at 2 P.M., on the following Thursday, Friday, Saturday, Monday, and Tuesday, from 10 to 11 A.M., punctually, for the objects stated in the Rules of the Association, and specified below.

The business is to be conducted in the following manner:—

At the first meeting, one of the Secretaries will read the Minutes of last year's proceedings, as recorded in the Minute-Book, and the Synopsis of Recommendations adopted at the last Meeting of the Association and printed in the last volume of the Transactions. He will next proceed to read the Report of the Organizing Committee †. The List of Communications to be read on Thursday shall be then arranged, and the general distribution of business throughout the week shall be provisionally appointed. At the close of the Committee Meeting the Secretaries shall forward to the Printer a List of the Papers appointed to be read. The Printer is charged with publishing the same before 8 A.M. on Thursday in the Journal.

On the second day of the Annual Meeting, and the following days, the

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read, are now as far as possible determined by Organizing Committees for the several Sections *before the beginning of the Meeting*. It has therefore become necessary, in order to give an opportunity to the Committees of doing justice to the several Communications, that each Author should prepare an Abstract of his Memoir, of a length suitable for insertion in the published Transactions of the Association, and that he should send it, together with the original Memoir, by book-post, on or before ...., addressed thus—"General Secretaries, British Association, 22 Albemarle Street, London, W. For Section ......" If it should be inconvenient to the Author that his Paper should be read on any particular days, he is requested to send information thereof to the Secretaries in a separate note.

* Passed by the General Committee, Edinburgh, 1871.

† This and the following sentence were added by the General Committee, 1871.

Secretaries are to correct, on a copy of the Journal, the list of papers which have been read on that day, to add to it a list of those appointed to be read on the next day, and to send this copy of the Journal as early in the day as possible to the Printers, who are charged with printing the same before 8 A.M. next morning in the Journal. It is necessary that one of the Secretaries of each Section should call at the Printing Office and revise the proof each evening.

Minutes of the proceedings of every Committee are to be entered daily in the Minute-Book, which should be confirmed at the next meeting of the Committee.

Lists of the Reports and Memoirs read in the Sections are to be entered in the Minute-Book daily, which, with *all Memoirs and Copies or Abstracts of Memoirs furnished by Authors, are to be forwarded, at the close of the Sectional Meetings*, to the Assistant General Secretary.

The Vice-Presidents and Secretaries of Sections become *ex officio* temporary Members of the General Committee (*vide* p. xix), and will receive, on application to the Treasurer in the Reception Room, Tickets entitling them to attend its Meetings.

The Committees will take into consideration any suggestions which may be offered by their Members for the advancement of Science. They are specially requested to review the recommendations adopted at preceding Meetings, as published in the volumes of the Association and the communications made to the Sections at this Meeting, for the purposes of selecting definite points of research to which individual or combined exertion may be usefully directed, and branches of knowledge on the state and progress of which Reports are wanted; to name individuals or Committees for the execution of such Reports or researches; and to state whether, and to what degree, these objects may be usefully advanced by the appropriation of the funds of the Association, by application to Government, Philosophical Institutions, or Local Authorities.

In case of appointment of Committees for special objects of Science, it is expedient that *all Members of the Committee should be named, and one of them appointed to act as Secretary, for insuring attention to business.*

Committees have power to add to their number persons whose assistance they may require.

The recommendations adopted by the Committees of Sections are to be registered in the Forms furnished to their Secretaries, and one Copy of each is to be forwarded, without delay, to the Assistant-General Secretary for presentation to the Committee of Recommendations. *Unless this be done, the Recommendations cannot receive the sanction of the Association.*

N.B.—Recommendations which may originate in any one of the Sections must *first be sanctioned by the Committee of that Section* before they can be referred to the Committee of Recommendations or confirmed by the General Committee.

Notices Regarding Grants of Money.

Committees and individuals, to whom grants of money have been entrusted by the Association for the prosecution of particular researches in Science, are required to present to each following Meeting of the Association a Report of the progress which has been made; and the Individual or the Member first named of a Committee to whom a money grant has been made must (previously to the next meeting of the Association) forward to the General

Secretaries or Treasurer a statement of the sums which have been expended, and the balance which remains disposable on each grant.

Grants of money sanctioned at any one meeting of the Association expire *a week before* the opening of the ensuing Meeting; nor is the Treasurer authorized, after that date, to allow any claims on account of such grants, unless they be renewed in the original or a modified form by the General Committee.

No Committee shall raise money in the name or under the auspices of the British Association without special permission from the General Committee to do so; and no money so raised shall be expended except in accordance with the rules of the Association.

In each Committee, the Member first named is the only person entitled to call on the Treasurer, W. Spottiswoode, Esq., 50 Grosvenor Place, London, S.W., for such portion of the sums granted as may from time to time be required.

In grants of money to Committees, the Association does not contemplate the payment of personal expenses to the members.

In all cases where additional grants of money are made for the continuation of Researches at the cost of the Association, the sum named is deemed to include, as a part of the amount, whatever balance may remain unpaid on the former grant for the same object.

All Instruments, Papers, Drawings, and other property of the Association are to be deposited at the Office of the Association, 22 Albemarle Street, Piccadilly, London, W., when not employed in carrying on scientific inquiries for the Association.

Business of the Sections.

The Meeting Room of each Section is opened for conversation from 10 to 11 daily. *The Section Rooms and approaches thereto can be used for no notices, exhibitions, or other purposes than those of the Association.*

At 11 precisely the Chair will be taken, and the reading of communications, in the order previously made public, be commenced. At 3 P.M. the Sections will close.

Sections may, by the desire of the Committees, divide themselves into Departments, as often as the number and nature of the communications delivered in may render such divisions desirable.

A Report presented to the Association, and read to the Section which originally called for it, may be read in another Section, at the request of the Officers of that Section, with the consent of the Author.

Duties of the Doorkeepers.

1.—To remain constantly at the Doors of the Rooms to which they are appointed during the whole time for which they are engaged.

2.—To require of every person desirous of entering the Rooms the exhibition of a Member's, Associate's or Lady's Ticket, or Reporter's Ticket, signed by the Treasurer, or a Special Ticket, signed by the Assistant-General Secretary.

3.—Persons unprovided with any of these Tickets can only be admitted to any particular Room by order of the Secretary in that Room.

No person is exempt from these Rules, except those Officers of the Association whose names are printed in the Programme, p. 1.

Duties of the Messengers.

To remain constantly at the Rooms to which they are appointed, during the whole time for which they are engaged, except when employed on messages by one of the Officers directing these Rooms.

Committee of Recommendations.

The General Committee shall appoint at each Meeting a Committee, which shall receive and consider the Recommendations of the Sectional Committees, and report to the General Committee the measures which they would advise to be adopted for the advancement of Science.

All Recommendations of Grants of Money, Requests for Special Researches, and Reports on Scientific Subjects shall be submitted to the Committee of Recommendations, and not taken into consideration by the General Committee unless previously recommended by the Committee of Recommendations.

Local Committees.

Local Committees shall be formed by the Officers of the Association to assist in making arrangements for the Meetings.

Local Committees shall have the power of adding to their numbers those Members of the Association whose assistance they may desire.

Officers.

A President, two or more Vice-Presidents, one or more Secretaries, and a Treasurer shall be annually appointed by the General Committee.

Council.

In the intervals of the Meetings, the affairs of the Association shall be managed by a Council appointed by the General Committee. The Council may also assemble for the despatch of business during the week of the Meeting.

Papers and Communications.

The Author of any paper or communication shall be at liberty to reserve his right of property therein.

Accounts.

The Accounts of the Association shall be audited annually, by Auditors appointed by the General Committee.

Table showing the Places and Times of Meeting of the British Association, with Presidents, Vice-Presidents, and Local Secretaries, from its Commencement.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
The EARL FITZWILLIAM, D.C.L., F.R.S., F.G.S., &c. YORK, September 27, 1831.	Rev. W. Vernon Harcourt, M.A., F.R.S., F.G.S.	William Gray, jun., F.G.S. Professor Phillips, M.A., F.R.S., F.G.S.
The REV. W. BUCKLAND, D.D., F.R.S., F.G.S., &c. OXFORD, June 19, 1832.	Sir David Brewster, F.R.S. L. & E., &c. Rev. W. Whewell, F.R.S., Pres. Geol. Soc.	Professor Daubeny, M.D., F.R.S., &c. Rev. Professor Powell, M.A., F.R.S., &c.
The REV. ADAM SEDGWICK, M.A., V.P.R.S., V.P.G.S. CAMBRIDGE, June 25, 1833.	G. B. Airy, F.R.S., Astronomer Royal, &c. John Dalton, D.C.L., F.R.S.	Rev. Professor Henslow, M.A., F.L.S., F.G.S. Rev. W. Whewell, F.R.S.
SIR T. MACDOUGALL BRISBANE, K.C.B., D.C.L., F.R.S. L. & E. EDINBURGH, September 8, 1834.	Sir David Brewster, F.R.S., &c. Rev. T. R. Robinson, D.D.	Professor Forbes, F.R.S. L. & E., &c. Sir John Robinson, Sec. R.S.E.
The REV. PROVOST LLOYD, LL.D. DUBLIN, August 10, 1835.	Viscount Oxmantown, F.R.S., F.R.A.S. Rev. W. Whewell, F.R.S., &c.	Sir W. R. Hamilton, Astron. Royal of Ireland, &c. Rev. Professor Lloyd, F.R.S.
The MARQUIS OF LANSDOWNE, D.C.L., F.R.S., &c. BRISTOL, August 22, 1836.	The Marquis of Northampton, F.R.S. Rev. W. D. Conybeare, F.R.S., F.G.S. J. C. Prichard, M.D., F.R.S.	Professor Daubeny, M.D., F.R.S., &c. V. F. Hovenden, Esq.
The EARL OF BURLINGTON, F.R.S., F.G.S., Chancellor of the University of London LIVERPOOL, September 11, 1837.	The Bishop of Norwich, P.L.S., F.G.S. John Dalton, D.C.L., F.R.S. Sir Philip de Grey Egerton, Bart., F.R.S., F.G.S. Rev. W. Whewell, F.R.S.	Professor Traill, M.D. Wm. Wallace Currie, Esq. Joseph N. Walker, Pres. Royal Institution, Liverpool.
The DUKE OF NORTHUMBERLAND, F.R.S., F.G.S., &c. NEWCASTLE-ON-TYNE, August 20, 1838.	The Bishop of Durham, F.R.S., F.S.A. The Rev. W. Vernon Harcourt, F.R.S., &c. Prideaux John Selby, Esq., F.R.S.E.	John Adamson, F.L.S., &c. Wm. Hutton, F.G.S. Professor Johnston, M.A., F.R.S.
The REV. W. VERNON HARCOURT, M.A., F.R.S., &c. BIRMINGHAM, August 26, 1839.	Marquis of Northampton. Earl of Dartmouth. The Rev. T. R. Robinson, D.D. John Corrie, Esq., F.R.S. Very Rev. Principal Macfarlane	George Barker, Esq., F.R.S. Peyton Blakiston, M.D. Joseph Hodgson, Esq., F.R.S. Follett Osler, Esq.
The MARQUIS OF BREADALBANE, F.R.S. GLASGOW, September 17, 1840.	Major-General Lord Greenock, F.R.S.E. Sir David Brewster, F.R.S. Sir T. M. Brisbane, Bart., F.R.S. The Earl of Mount Edgecumbe.	Andrew Liddell, Esq. Rev. J. P. Nicol, LL.D. John Strang, Esq.
The REV. PROFESSOR WHEWELL, F.R.S., &c. PLYMOUTH, July 29, 1841.	The Earl of Morley. Lord Eliot, M.P. Sir C. Lemon, Bart. Sir D. T. Acland, Bart.	W. Snow Harris, Esq., F.R.S. Col. Hamilton Smith, F.L.S. Robert Were Fox, Esq. Richard Taylor, jun., Esq.
The LORD FRANCIS EGERTON, F.G.S. MANCHESTER, June 23, 1842.	John Dalton, D.C.L., F.R.S. Hon. and Rev. W. Herbert, F.L.S., &c. Rev. A. Sedgwick, M.A., F.R.S. W. C. Henry, M.D., F.R.S. Sir Benjamin Heywood, Bart.	Peter Clare, Esq., F.R.A.S. W. Fleming, M.D. James Heywood, Esq., F.R.S.
The EARL OF ROSSE, F.R.S. CORK, August 17, 1843.	Earl of Listowel. Viscount Adare Sir W. R. Hamilton, Pres. R.I.A. Rev. T. R. Robinson D.D.	Professor John Stevelly, M.A. Rev. Jos. Carson, F.T.C. Dublin. William Keleher, Esq. Wm. Clear, Esq.

The REV. G. PEACOCK, D.D. (Dean of Ely), F.R.S. YORK, September 26, 1844.	Earl Fitzwilliam, F.R.S. Viscount Morpeth, F.G.S. The Hon. John Stuart Wortley, M.P. Sir David Brewster, K.H., F.R.S. Michael Faraday, Esq., D.C.L., F.R.S. Rev. W. V. Harcourt, F.R.S.	William Hatfeild, Esq., F.G.S. Thomas Meynell, Esq., F.L.S. Rev. W. Scoresby, LL.D., F.R.S. William West, Esq.
SIR JOHN F. W. HERSCHEL, Bart., F.R.S., &c. CAMBRIDGE, June 19, 1845.	The Earl of Hardwicke. The Bishop of Norwich Rev. J. Graham, D.D. Rev. G. Ainslie, D.D. G. B. Airy, Esq., M.A., D.C.L., F.R.S. The Rev. Professor Sedgwick, M.A., F.R.S.	William Hopkins, Esq., M.A., F.R.S. Professor Ansted, M.A., F.R.S.
SIR RODERICK IMPEY MURCHISON, G.C.St.S., F.R.S. SOUTHAMPTON, September 10, 1846.	The Marquis of Winchester. The Earl of Yarborough, D.C.L. Lord Ashburton, D.C.L. Viscount Palmerston, M.P. Right Hon. Charles Shaw Lefevre, M.P. Sir George T. Staunton, Bart., M.P., D.C.L., F.R.S. The Lord Bishop of Oxford, F.R.S. Professor Owen, M.D., F.R.S. Professor Powell, F.R.S.	Henry Clark, M.D. T. H. C. Moody, Esq.
SIR ROBERT HARRY INGLIS, Bart., D.C.L., F.R.S., M.P. for the University of Oxford OXFORD, June 23, 1847.	The Earl of Rosse, F.R.S. The Lord Bishop of Oxford, F.R.S. The Vice-Chancellor of the University Thomas G. Bucknall Estcourt, Esq., D.C.L., M.P. for the University of Oxford. Very Rev. the Dean of Westminster, D.D., F.R.S. Professor Daubeny, M.D., F.R.S. The Rev. Prof. Powell, M.A., F.R.S.	Rev. Robert Walker, M.A., F.R.S. H. Wentworth Acland, Esq., B.M.
The MARQUIS OF NORTHAMPTON, President of the Royal Society, &c. SWANSEA, August 9, 1848.	The Marquis of Bute, K.T. Viscount Adare, F.R.S. Sir H. T. DelaBeche, F.R.S., Pres. G.S. The Very Rev. the Dean of Llandaff, F.R.S. Lewis W. Dillwyn, Esq., F.R.S. W. R. Grove, Esq., F.R.S. J. H. Vivian, Esq., M.P., F.R.S. The Lord Bishop of St. David's	Matthew Moggridge, Esq. D. Nicol, M.D.
The REV. T. R. ROBINSON, D.D., M.R.I.A., F.R.A.S. BIRMINGHAM, September 12, 1849.	The Earl of Harrowby. The Lord Wrottesley, F.R.S. Right Hon. Sir Robert Peel, Bart., M.P., D.C.L., F.R.S. Charles Darwin, Esq., M.A., F.R.S., Sec. G.S. Professor Faraday, D.C.L., F.R.S. Sir David Brewster, K.H., LL.D., F.R.S. Rev. Prof. Willis, M.A., F.R.S.	Captain Tindal, R.N. William Wills, Esq. Bell Fletcher, Esq., M.D. James Chance, Esq.
SIR DAVID BREWSTER, K.H., LL.D., F.R.S. L. & E., Principal of the United College of St. Salvator and St. Leonard, St. Andrews. EDINBURGH, July 21, 1850.	Right Hon. the Lord Provost of Edinburgh The Earl of Cathcart, K.C.B., F.R.S.E. The Earl of Rosebery, K.T., D.C.L., F.R.S. Right Hon. David Boyle (Lord Justice-General), F.R.S.E. General Sir Thomas M. Brisbane, Bart., D.C.L., F.R.S., Pres. R.S.E. Very Rev. John Lee, D.D., V.P.R.S.E., Principal of the University of Edinburgh. Professor W. P. Alison, M.D., V.P.R.S.E. Professor J. D. Forbes, F.R.S., Sec. R.S.E.	Rev. Professor Kelland, M.A., F.R.S.L. & E. Professor Balfour, M.D., F.R.S.E., F.L.S. James Tod, Esq., F.R.S.E.
GEORGE BIDDELL AIRY, Esq., D.C.L., F.R.S., Astronomer Royal IPSWICH, July 2, 1851.	The Lord Rendlesham, M.P. The Lord Bishop of Norwich Rev. Professor Sedgwick, M.A., F.R.S. Rev. Professor Henslow, M.A., F.L.S. Sir John P. Boileau, Bart., F.R.S. Sir William F. F. Middleton, Bart. J. C. Cobbold, Esq., M.P. T. B. Western, Esq.	Charles May, Esq., F.R.A.S. Dillwyn Sims, Esq. George Arthur Biddell, Esq. George Ransome, Esq., F.L.S.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
COLONEL EDWARD SABINE, Royal Artillery, Treas. & V.P. of the Royal Society BELFAST, September 1, 1852.	The Earl of Enniskillen, D.C.L., F.R.S. The Earl of Rosse, M.R.I.A., Pres. R.S. Sir Henry T. DelaBeche, F.R.S. Rev. Edward Hincks, D.D., M.R.I.A. Rev. P. S. Henry, D.D., Pres. Queen's College, Belfast Rev. T. R. Robinson, D.D., Pres. R.I.A., F.R.A.S. Professor G. G. Stokes, F.R.S. Professor Stevelly, LL.D.	W. J. C. Allen, Esq. William M'Gee, M.D. Professor W. P. Wilson.
WILLIAM HOPKINS, Esq., M.A., V.P.R.S., F.G.S., & Pres. Camb. Phil. Society HULL, September 7, 1853.	The Earl of Carlisle, F.R.S. Lord Londesborough, F.R.S. Professor Faraday, D.C.L., F.R.S. Rev. Prof. Sedgwick, M.A., F.R.S. Charles Frost, Esq., F.S.A., Pres. of the Hull Lit. and Philos. Society William Spence, Esq., F.R.S. Lieut.-Col. Sykes, F.R.S. Professor Wheatstone, F.R.S.	Henry Cooper, M.D., V.P. Hull. Lit. & Phil. Society. Bethel Jacobs, Esq., Pres. Hull Mechanics' Inst.
The EARL OF HARROWBY, F.R.S. LIVERPOOL, September 20, 1854.	The Lord Wrottesley, M.A., F.R.S., F.R.A.S. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. Professor Owen, M.D., LL.D., F.R.S., F.L.S., F.G.S. Rev. Professor Whewell, D.D., F.R.S., Hon. M.R.I.A., F.G.S., Master of Trinity College, Cambridge William Lassell, Esq., F.R.S.L. & E., F.R.A.S. Joseph Brooks Yates, F.S.A., F.R.G.S.	Joseph Dickinson, M.D., F.R.S. Thomas Inman, M.D.
The DUKE OF ARGYLL, F.R.S., F.G.S. GLASGOW, September 12, 1855.	The Very Rev. Principal Macfarlane, D.D. Sir William Jardine, Bart., F.R.S.E. Sir Charles Lyell, M.A., LL.D., F.R.S. James Smith, Esq., F.R.S. L. & E. Walter Crum, Esq., F.R.S. Thomas Graham, Esq., M.A., F.R.S., Master of the Royal Mint Professor William Thomson, M.A., F.R.S.	John Strang, LL.D. Professor Thomas Anderson, M.D. William Gourlie, Esq.
CHARLES G. B. DAUBENY, M.D., LL.D., F.R.S., Professor of Botany in the University of Oxford CHELTENHAM, August 6, 1856.	The Earl of Ducie, F.R.S., F.G.S. The Lord Bishop of Gloucester and Bristol Sir Roderick I. Murchison, G.C.St.S., D.C.L., F.R.S. Thomas Barwick Lloyd Baker, Esq. The Rev. Francis Close, M.A.	Capt. Robinson, R.A. Richard Beamish, Esq., F.R.S. John West Hugall, Esq.
The REV. HUMPHREY LLOYD, D.D., D.C.L., F.R.S. L. & E., V.P.R.I.A. DUBLIN, August 26, 1857.	The Right Honourable the Lord Mayor of Dublin The Provost of Trinity College, Dublin The Marquis of Kildare. Lord Talbot de Malahide The Lord Chancellor of Ireland The Lord Chief Baron, Dublin Sir William R. Hamilton, LL.D., F.R.A.S., Astronomer Royal of Ireland Lieut.-Colonel Larcom, R.E., LL.D., F.R.S. Richard Griffith, Esq., LL.D., M.R.I.A., F.R.S.E., F.G.S.	Lundy E. Foote, Esq. Rev. Professor Jellett, F.T.C.D. W. Neilson Hancock, LL.D.
RICHARD OWEN, M.D., D.C.L., V.P.R.S., F.L.S., F.G.S., Superintendent of the Natural-History Departments of the British Museum LEEDS, September 22, 1858.	The Lord Monteagle, F.R.S. The Lord Viscount Goderich, M.P., F.R.G.S. The Right Hon. M. T. Baines, M.A., M.P. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. The Rev. W. Whewell, D.D., F.R.S., Hon. M.R.I.A., F.G.S., F.R.A.S., Master of Trinity College, Cambridge James Garth Marshall, Esq., M.A., F.G.S. R. Monckton Milnes, Esq., D.C.L., M.P., F.R.G.S.	Rev. Thomas Hincks, B.A. W. Sykes Ward, Esq., F.C.S. Thomas Wilson, Esq., M.A.

HIS ROYAL HIGHNESS THE PRINCE CONSORT ABERDEEN, September 14, 1859.	The Duke of Richmond, K.G., F.R.S. The Earl of Aberdeen, LL.D., K.G., K.T., F.R.S. The Lord Provost of the City of Aberdeen Sir John F. W. Herschel, Bart., M.A., D.C.L., F.R.S. Sir David Brewster, K.H., D.C.L., F.R.S. Sir Roderick I. Murchison, G.C.St.S., D.C.L., F.R.S. The Rev. W. V. Harcourt, M.A., F.R.S. The Rev. T. R. Robinson, D.D., F.R.S. A. Thomson, Esq., LL.D., F.R.S., Convener of the County of Aberdeen	Professor J. Nicol, F.R.S.E., F.G.S. Professor Fuller, M.A. John F. White, Esq.
The LORD WROTTESLEY, M.A., V.P.R.S., F.R.A.S. OXFORD, June 27, 1860.	The Earl of Derby, K.G., P.C., D.C.L., Chancellor of the Univ. of Oxford The Rev. F. Jeune, D.C.L., Vice-Chancellor of the University of Oxford The Duke of Marlborough, D.C.L., F.G.S., Lord Lieutenant of Oxfordshire The Earl of Rosse, K.P., M.A., F.R.S., F.R.A.S. The Lord Bishop of Oxford, D.D., F.R.S. The Very Rev. H. G. Liddell, D.D., Dean of Christ Church, Oxford Professor Daubeny, M.D., LL.D., F.R.S., F.L.S., F.G.S. Professor Acland, M.D., F.R.S. Professor Donkin, M.A., F.R.S., F.R.A.S.	George Rolleston, M.D., F.L.S. H. J. S. Smith, Esq., M.A., F.C.S. George Griffith, Esq., M.A., F.C.S.
WILLIAM FAIRBAIRN, Esq., LL.D., C.E., F.R.S. MANCHESTER, September 4, 1861.	The Earl of Ellesmere, F.R.G.S. The Lord Stanley, M.P., D.C.L., F.R.G.S. The Lord Bishop of Manchester, D.D., F.R.S., F.G.S. Sir Philip de M. Grey Egerton, Bart., M.P., F.R.S., F.G.S. Sir Benjamin Heywood, Bart., F.R.S. Thomas Bazley, Esq., M.P. James Aspinall Turner, Esq., M.P. James Prescott Joule, Esq., LL.D., F.R.S., Pres. Lit. & Phil. Soc. Manchester Professor E. Hodgkinson, F.R.S., M.R.I.A., M.I.C.E. Joseph Whitworth, Esq., F.R.S., M.I.C.E.	R. D. Darbishire, Esq., B.A., F.G.S. Alfred Neild, Esq. Arthur Ransome, M.A., Esq. Professor H. E. Roscoe, B.A.
The REV. R. WILLIS, M.A., F.R.S., Jacksonian Professor of Natural and Experimental Philosophy in the University of Cambridge CAMBRIDGE, October 1, 1862.	The Rev. the Vice-Chancellor of the University of Cambridge The Very Rev. Harvey Goodwin, D.D., Dean of Ely The Rev. W. Whewell, D.D., F.R.S., Master of Trinity College, Cambridge The Rev. Professor Sedgwick, M.A., D.C.L., F.R.S. Rev. J. Challis, M.A., F.R.S. G. B. Airy, Esq., M.A., D.C.L., F.R.S., Astronomer Royal Professor G. G. Stokes, M.A., D.C.L., Sec. R.S. Professor J. C. Adams, M.A., D.C.L., F.R.S., Pres. C.P.S.	Professor C. C. Babington, M.A., F.R.S., F.L.S. Professor G. D. Liveing, M.A. The Rev. N. M. Ferrers, M.A.
SIR W. ARMSTRONG, C.B., LL.D., F.R.S. NEWCASTLE-ON-TYNE, August 26, 1863.	Sir Walter C. Trevelyan, Bart., M.A. Sir Charles Lyell, LL.D., D.C.L., F.R.S., F.G.S. Hugh Taylor, Esq., Chairman of the Coal Trade Isaac Lowthian Bell, Esq., Mayor of Newcastle Nicholas Wood, Esq., President of the Northern Institute of Mining Engineers Rev. Temple Chevallier, B.D., F.R.A.S. William Fairbairn, Esq., LL.D., F.R.S.	A. Noble, Esq. Augustus H. Hunt, Esq. R. C. Clapham, Esq.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
SIR CHARLES LYELL, Bart., M.A., D.C.L., F.R.S. BATH, September 14, 1864.	The Right Hon. the Earl of Cork and Orrery, Lord Lieutenant of Somersetshire The Most Noble the Marquis of Bath The Right Hon. Earl Nelson The Right Hon. Lord Portman The Very Reverend the Dean of Hereford The Venerable the Archdeacon of Bath W. Tite, Esq., M.P., F.R.S., F.G.S., F.S.A. A. E. Way, Esq., M.P. Francis H. Dickinson, Esq. W. Sanders, Esq., F.R.S., F.G.S.	C. Moore, Esq., F.G.S. C. E. Davis, Esq. The Rev. H. H. Winwood, M.A.
JOHN PHILLIPS, Esq., M.A., LL.D., F.R.S., F.G.S., Professor of Geology in the University of Oxford BIRMINGHAM, September 6, 1865.	The Right Hon. the Earl of Lichfield, Lord-Lieutenant of Staffordshire The Right Hon. the Earl of Dudley The Right Hon. Lord Leigh, Lord-Lieutenant of Warwickshire The Right Hon. Lord Lyttelton, Lord-Lieutenant of Worcestershire The Right Hon. Lord Wrottesley, M.A., D.C.L., F.R.S., F.R.A.S. The Right Reverend the Lord Bishop of Worcester The Right Hon. C. B. Adderley, M.P. William Scholefield, Esq., M.P. F. Osler, Esq., F.R.S. J. T. Chance, Esq. The Rev. Charles Evans, M.A.	William Mathews, Esq., jun., F.G.S. John Henry Chamberlain, Esq. The Rev. G. D. Boyle, M.A.
WILLIAM R. GROVE, Esq., Q.C., M.A., F.R.S. NOTTINGHAM, August 22, 1866.	His Grace the Duke of Devonshire, Lord-Lieutenant of Derbyshire His Grace the Duke of Rutland, Lord-Lieutenant of Leicestershire The Right Hon. Lord Belper, Lord-Lieutenant of Nottinghamshire The Right Hon. J. E. Denison, M.P. J. C. Webb, Esq., High-Sheriff of Nottinghamshire Thomas Graham, Esq., F.R.S., Master of the Mint Joseph Hooker, M.D., F.R.S., F.L.S. John Russell Hinds, Esq., F.R.S., F.R.A.S. T. Close, Esq.	Dr. Robertson. Edward J. Lowe, Esq., F.R.A.S., F.L.S. The Rev. J. F. M'Callan, M.A.
HIS GRACE THE DUKE OF BUCCLEUCH, K.G., D.C.L., F.R.S. DUNDEE, September 4, 1867.	The Right Hon. the Earl of Airlie, K.T. The Right Hon. the Lord Kinnaird, K.T. Sir John Ogilvy, Bart., M.P. Sir Roderick I. Murchison, Bart., K.C.B., LL.D., F.R.S., F.G.S., &c. Sir David Baxter, Bart. Sir David Brewster, D.C.L., F.R.S., Principal of the University of Edinburgh James D. Forbes, LL.D., F.R.S., Principal of the United College of St. Salvator and St. Leonards, University of St. Andrews	J. Henderson, Esq., jun. John Austin Lake Gloag, Esq. Patrick Anderson, Esq.

JOSEPH DALTON HOOKER, M.D., D.C.L., F.R.S., F.L.S. NORWICH, August 19, 1868.	The Right Hon. the Earl of Leicester, Lord-Lieutenant of Norfolk Sir John Peter Boileau, Bart., F.R.S. The Rev. Adam Sedgwick, M.A., LL.D., F.R.S., F.G.S., &c., Woodwardian Professor of Geology in the University of Cambridge Sir John Lubbock, Bart., F.R.S., F.L.S., F.G.S. John Couch Adams, Esq., M.A., D.C.L., F.R.S., F.R.A.S., Lowndean Professor of Astronomy and Geometry in the University of Cambridge Thomas Brightwell, Esq.	Dr. Donald Dalrymple. Rev. Joseph Crompton, M.A. Rev. Canon Hinds Howell.
PROFESSOR GEORGE G. STOKES, D.C.L., F.R.S. EXETER, August 18, 1869.	The Right Hon. the Earl of Devon The Right Hon. Sir Stafford H. Northcote, C.B., Bart., M.P., &c. Sir John Bowring, LL.D., F.R.S. William B. Carpenter, M.D., F.R.S., F.L.S. Robert Were Fox, Esq., F.R.S. W. H. Fox Talbot, Esq., M.A., LL.D., F.R.S., F.L.S.	Henry S. Ellis, Esq., F.R.A.S. John C. Bowring, Esq. The Rev. R. Kirwan.
PROFESSOR T. H. HUXLEY, LL.D., F.R.S., F.G.S. LIVERPOOL, September 14, 1870.	The Right Hon. the Earl of Derby, LL.D., F.R.S. Sir Philip De M. Grey Egerton, Bart., M.P. The Right Hon. W. E. Gladstone, D.C.L., M.P. S. R. Graves, Esq., M.P. Sir Joseph Whitworth, Bart., LL.D., D.C.L., F.R.S. James P. Joule, LL.D., D.C.L., F.R.S. Joseph Mayer, Esq., F.S.A., F.R.G.S.	Rev. W. Banister. Reginald Harrison, Esq. Rev. Henry H. Higgins, M.A. Rev. Dr. A. Hume, F.S.A.
PROFESSOR SIR WILLIAM THOMSON, M.A., LL.D., F.R.SS.L. & E. EDINBURGH, August 2, 1871.	His Grace the Duke of Buccleuch, K.G., D.C.L., F.R.S. The Right Hon. the Lord Provost of Edinburgh The Right Hon. John Inglis, LL.D., Lord Justice-General of Scotland Sir Alexander Grant, Bart., M.A., Principal of the University of Edinburgh Sir Roderick I. Murchison, Bart., K.C.B., G.C.St.S., D.C.L., F.R.S. Sir Charles Lyell, Bart., D.C.L., F.R.S., F.G.S. Dr. Lyon Playfair, M.P., C.B., F.R.S. Professor Christison, M.D., D.C.L., Pres. R.S.E. Professor Balfour, F.R.SS.L. & E.	Professor A. Crum Brown, M.D., F.R.S.E. J. D. Marwick, Esq., F.R.S.E.
DR. W. B. CARPENTER, LL.D., F.R.S., F.L.S. BRIGHTON, August 14, 1872.	The Earl of Chichester, Lord-Lieutenant of the County of Sussex The Duke of Norfolk The Right Hon. the Duke of Richmond, K.G., P.C., D.C.L. The Right Hon. the Duke of Devonshire, K.G., D.C.L., F.R.S. Sir John Lubbock, Bart., M.P., F.R.S., F.L.S., F.G.S. Dr. Sharpey, LL.D., Sec. R.S., F.L.S. J. Prestwich, Esq., F.R.S., Pres. G.S.	Charles Carpenter, Esq. The Rev. Dr. Griffith. Henry Willett, Esq.
JAMES PRESCOTT JOULE, D.C.L., LL.D., F.R.S. BRADFORD, September 17, 1873.	The Earl of Rosse, F.R.S., F.R.A.S. Lord Houghton, D.C.L., F.R.S. The Right Hon. W. E. Forster, M.P. The Mayor of Bradford J. P. Gassiot, Esq., D.C.L., F.R.S. Professor Phillips, D.C.L., F.R.S. John Hawkshaw, Esq., F.R.S., F.G.S.	The Rev. J. R. Campbell, D.D. Richard Goddard, Esq. Peile Thompson, Esq.

Presidents and Secretaries of the Sections of the Association.

Date and Place.	Presidents.	Secretaries.
	MATHEMATICAL AND PHYSICAL SCIENCES.	
	COMMITTEE OF SCIENCES, I.—MATHEMATICS AND GENERAL PHYSICS.	
1832. Oxford	Davies Gilbert, D.C.L., F.R.S....	Rev. H. Coddington.
1833. Cambridge	Sir D. Brewster, F.R.S............	Prof. Forbes.
1834. Edinburgh	Rev. W. Whewell, F.R.S..........	Prof. Forbes, Prof. Lloyd.
	SECTION A.—MATHEMATICS AND PHYSICS.	
1835. Dublin	Rev. Dr. Robinson..................	Prof. Sir W. R. Hamilton, Prof. Wheatstone.
1836. Bristol	Rev. William Whewell, F.R.S....	Prof. Forbes, W. S. Harris, F. W. Jerrard.
1837. Liverpool ..	Sir D. Brewster, F.R.S............	W. S. Harris, Rev. Prof. Powell, Prof. Stevelly.
1838. Newcastle...	Sir J. F. W. Herschel, Bart., F.R.S.	Rev. Prof. Chevallier, Major Sabine, Prof. Stevelly.
1839. Birmingham	Rev. Prof. Whewell, F.R.S.	J. D. Chance, W. Snow Harris, Prof. Stevelly.
1840. Glasgow ...	Prof. Forbes, F.R.S.	Rev. Dr. Forbes, Prof. Stevelly, Arch. Smith.
1841. Plymouth...	Rev. Prof. Lloyd, F.R.S.	Prof. Stevelly.
1842. Manchester	Very Rev. G. Peacock, D.D., F.R.S.	Prof. M'Culloch, Prof. Stevelly, Rev. W. Scoresby.
1843. Cork	Prof. M'Culloch, M.R.I.A.	J. Nott, Prof. Stevelly.
1844. York.........	The Earl of Rosse, F.R.S..........	Rev. Wm. Hey, Prof. Stevelly.
1845. Cambridge..	The Very Rev. the Dean of Ely .	Rev. H. Goodwin, Prof. Stevelly, G. G. Stokes.
1846. Southampton	Sir John F. W. Herschel, Bart., F.R.S.	John Drew, Dr. Stevelly, G. G. Stokes.
1847. Oxford	Rev. Prof. Powell, M.A., F.R.S. .	Rev. H. Price, Prof. Stevelly, G. G. Stokes.
1848. Swansea	Lord Wrottesley, F.R.S.	Dr. Stevelly, G. G. Stokes.
1849. Birmingham	William Hopkins, F.R.S.........	Prof. Stevelly, G. G. Stokes, W. Ridout Wills.
1850. Edinburgh..	Prof. J. D. Forbes, F.R.S., Sec R.S.E.	W. J. Macquorn Rankine, Prof. Smyth, Prof. Stevelly, Prof. G. G. Stokes.
1851. Ipswich......	Rev. W. Whewell, D.D., F.R.S., &c.	S. Jackson, W. J. Macquorn Rankine, Prof. Stevelly, Prof. G. G. Stokes.
1852. Belfast	Prof. W. Thomson, M.A., F.R.S. L. & E.	Prof. Dixon, W. J. Macquorn Rankine, Prof. Stevelly, J. Tyndall.
1853. Hull	The Dean of Ely, F.R.S.	B. Blaydes Haworth, J. D. Sollitt, Prof. Stevelly, J. Welsh.
1854. Liverpool...	Prof. G. G. Stokes, M.A., Sec. R.S.	J. Hartnup, H. G. Puckle, Prof. Stevelly, J. Tyndall, J. Welsh.
1855. Glasgow ...	Rev. Prof. Kelland, M.A., F.R.S. L. & E.	Rev. Dr. Forbes, Prof. D. Gray, Prof. Tyndall.
1856. Cheltenham	Rev. R. Walker, M.A., F.R.S. ...	C. Brooke, Rev. T. A. Southwood, Prof. Stevelly, Rev. J. C. Turnbull.
1857. Dublin	Rev. T. R. Robinson, D.D., F.R.S., M.R.I.A.	Prof. Curtis, Prof. Hennessy, P. A. Ninnis, W. J. Macquorn Rankine, Prof. Stevelly.

Date and Place.	Presidents.	Secretaries.
1858. Leeds	Rev. W. Whewell, D.D., V.P.R.S.	Rev. S. Earnshaw, J. P. Hennessy, Prof. Stevelly, H. J. S. Smith, Prof. Tyndall.
1859. Aberdeen ...	The Earl of Rosse, M.A., K.P., F.R.S.	J. P. Hennessy, Prof. Maxwell, H. J. S. Smith, Prof. Stevelly.
1860. Oxford	Rev. B. Price, M.A., F.R.S.	Rev. G. C. Bell, Rev. T. Rennison, Prof. Stevelly.
1861. Manchester.	G. B. Airy, M.A., D.C.L., F.R.S.	Prof. R. B. Clifton, Prof. H. J. S. Smith, Prof. Stevelly.
1862. Cambridge..	Prof. G. G. Stokes, M.A., F.R.S.	Prof. R. B. Clifton, Prof. H. J. S. Smith, Prof. Stevelly.
1863. Newcastle...	Prof. W. J. Macquorn Rankine, C.E., F.R.S.	Rev. N. Ferrers, Prof. Fuller, F. Jenkin, Prof. Stevelly, Rev. C. T. Whitley.
1864. Bath	Prof. Cayley, M.A., F.R.S., F.R.A.S.	Prof. Fuller, F. Jenkin, Rev. G. Buckle, Prof. Stevelly.
1865. Birmingham	W. Spottiswoode, M.A., F.R.S., F.R.A.S.	Rev. T. N. Hutchinson, F. Jenkin, G. S. Mathews, Prof. H. J. S. Smith, J. M. Wilson.
1866. Nottingham	Prof. Wheatstone, D.C.L., F.R.S.	Fleeming Jenkin, Prof. H. J. S. Smith, Rev. S. N. Swann.
1867. Dundee......	Prof. Sir W. Thomson, D.C.L., F.R.S.	Rev. G. Buckle, Prof. G. C. Foster, Prof. Fuller, Prof. Swan.
1868. Norwich ...	Prof. J. Tyndall, LL.D., F.R.S...	Prof. G. C. Foster, Rev. R. Harley, R. B. Hayward.
1869. Exeter	Prof. J. J. Sylvester, LL.D., F.R.S.	Prof. G. C. Foster, R. B. Hayward, W. K. Clifford.
1870. Liverpool ...	J. Clerk Maxwell, M.A., LL.D., F.R.S.	Prof. W. G. Adams, W. K. Clifford, Prof. G. C. Foster, Rev. W. Allen Whitworth.
1871. Edinburgh .	Prof. P. G. Tait, F.R.S.E.	Prof. W. G. Adams, J. T. Bottomley, Prof. W. K. Clifford, Prof. J. D. Everett, Rev. R. Harley.
1872. Brighton ...	W. De La Rue, D.C.L., F.R.S...	Prof. W. K. Clifford, J. W. L. Glaisher, Prof. A. S. Herschel, G. F. Rodwell.

CHEMICAL SCIENCE.

COMMITTEE OF SCIENCES, II.—CHEMISTRY, MINERALOGY.

1832. Oxford	John Dalton, D.C.L., F.R.S.......	James F. W. Johnston.
1833. Cambridge..	John Dalton, D.C.L., F.R.S.... .	Prof. Miller.
1834. Edinburgh...	Dr. Hope............................	Mr. Johnston, Dr. Christison.

SECTION B.—CHEMISTRY AND MINERALOGY.

1835. Dublin	Dr. T. Thomson, F.R.S.	Dr. Apjohn, Prof. Johnston.
1836. Bristol	Rev. Prof. Cumming...............	Dr. Apjohn, Dr. C. Henry, W. Herapath.
1837. Liverpool..	Michael Faraday, F.R.S.	Prof. Johnston, Prof. Miller, Dr. Reynolds.
1838. Newcastle...	Rev. William Whewell, F.R.S....	Prof. Miller, R. L. Pattinson, Thomas Richardson.
1839. Birmingham	Prof. T. Graham, F.R.S.	Golding Bird, M.D., Dr. J. B. Melson.
1840. Glasgow ...	Dr. Thomas Thomson, F.R.S. ...	Dr. R. D. Thomson, Dr. T. Clark, Dr. L. Playfair.
1841. Plymouth...	Dr. Daubeny, F.R.S.	J. Prideaux, Robert Hunt, W. M. Tweedy.
1842. Manchester.	John Dalton, D.C.L., F.R.S......	Dr. L. Playfair, R. Hunt, J. Graham.
1843. Cork	Prof. Apjohn, M.R.I.A.	R. Hunt, Dr. Sweeny.
1844. York	Prof. T. Graham, F.R.S.	Dr. R. Playfair, E. Solly, T. H. Barker.
1845. Cambridge..	Rev. Prof. Cumming...............	R. Hunt, J. P. Joule, Prof. Miller, E. Solly.

Date and Place.	Presidents.	Secretaries.
1846. Southampton	Michael Faraday, D.C.L., F.R.S.	Dr. Miller, R. Hunt, W. Randall.
1847. Oxford	Rev. W. V. Harcourt, M.A., F.R.S.	B. C. Brodie, R. Hunt, Prof. Solly.
1848. Swansea ...	Richard Phillips, F.R.S.	T. H. Henry, R. Hunt, T. Williams.
1849. Birmingham	John Percy, M.D., F.R.S..........	R. Hunt, G. Shaw.
1850. Edinburgh .	Dr. Christison, V.P.R.S.E.	Dr. Anderson, R. Hunt, Dr. Wilson.
1851. Ipswich ...	Prof. Thomas Graham, F.R.S....	T. J. Pearsall, W. S. Ward.
1852. Belfast	Thomas Andrews, M.D., F.R.S..	Dr. Gladstone, Prof. Hodges, Prof. Ronalds.
1853. Hull	Prof. J. F. W. Johnston, M.A., F.R.S.	H. S. Blundell, Prof. R. Hunt, T. J. Pearsall.
1854. Liverpool...	Prof. W. A. Miller, M.D., F.R.S.	Dr. Edwards, Dr. Gladstone, Dr. Price.
1855. Glasgow ...	Dr. Lyon Playfair, C.B., F.R.S..	Prof. Frankland, Dr. H. E. Roscoe.
1856. Cheltenham	Prof. B. C. Brodie, F.R.S.	J. Horsley, P. J. Worsley, Prof. Voelcker.
1857. Dublin	Prof. Apjohn, M.D., F.R.S., M.R.I.A.	Dr. Davy, Dr. Gladstone, Prof. Sullivan.
1858. Leeds	Sir J. F. W. Herschel, Bart., D.C.L.	Dr. Gladstone, W. Odling, R. Reynolds.
1859. Aberdeen ...	Dr. Lyon Playfair, C.B., F.R.S..	J. S. Brazier, Dr. Gladstone, G. D. Liveing, Dr. Odling.
1860. Oxford	Prof. B. C. Brodie, F.R.S.	A. Vernon Harcourt, G. D. Liveing, A. B. Northcote.
1861. Manchester.	Prof. W. A. Miller, M.D., F.R.S.	A. Vernon Harcourt, G. D. Liveing.
1862. Cambridge .	Prof. W. A. Miller, M.D., F.R.S.	H. W. Elphinstone, W. Odling, Prof. Roscoe.
1863. Newcastle...	Dr. Alex. W. Williamson, F.R.S.	Prof. Liveing, H. L. Pattinson, J. C. Stevenson.
1864. Bath	W. Odling, M.B., F.R.S., F.C.S.	A. V. Harcourt, Prof. Liveing, R. Biggs.
1865. Birmingham	Prof. W. A. Miller, M.D., V.P.R.S.	A. V. Harcourt, H. Adkins, Prof. Wanklyn, A. Winkler Wills.
1866. Nottingham	H. Bence Jones, M.D., F.R.S. ...	J. H. Atherton, Prof. Liveing, W. J. Russell, J. White.
1867. Dundee ...	Prof. T. Anderson, M.D., F.R.S.E.	A. Crum Brown, Prof. G. D. Liveing, W. J. Russell.
1868. Norwich ...	Prof. E. Frankland, F.R.S., F.C.S.	Dr. A. Crum Brown, Dr. W. J. Russell, F. Sutton.
1869. Exeter	Dr. H. Debus, F.R.S., F.C.S. ...	Prof. A. Crum Brown, M.D., Dr. W. J. Russell, Dr. Atkinson.
1870. Liverpool...	Prof. H. E. Roscoe, B.A., F.R.S., F.C.S.	Prof. A. Crum Brown, M.D., A. E. Fletcher, Dr. W. J. Russell.
1871. Edinburgh	Prof. T. Andrews, M.D., F.R.S.	J. T. Buchanan, W. N. Hartley, T. E. Thorpe.
1872. Brighton ...	Dr. J. H. Gladstone, F.R.S.......	Dr. Mills, W. Chandler Roberts, Dr. W. J. Russell, Dr. T. Wood.

GEOLOGICAL (AND, UNTIL 1851, GEOGRAPHICAL) SCIENCE.

COMMITTEE OF SCIENCES, III.—GEOLOGY AND GEOGRAPHY.

1832. Oxford	R. I. Murchison, F.R.S.	John Taylor.
1833. Cambridge .	G. B. Greenough, F.R.S.	W. Lonsdale, John Phillips.
1834. Edinburgh .	Prof. Jameson	Prof. Phillips, T. Jameson Torrie, Rev. J. Yates.

SECTION C.—GEOLOGY AND GEOGRAPHY.

1835. Dublin	R. J. Griffith	Captain Portlock, T. J. Torrie.
1836. Bristol	Rev. Dr. Buckland, F.R.S.—*Geography*. R. I. Murchison, F.R.S.	William Sanders, S. Stutchbury, T. J. Torrie.
1837. Liverpool...	Rev. Prof. Sedgwick, F.R.S.—*Geography*. G. B. Greenough, F.R.S.	Captain Portlock, R. Hunter.—*Geography*. Captain H. M. Denham, R.N.

Date and Place.	Presidents.	Secretaries.
1838. Newcastle...	C. Lyell, F.R.S., V.P.G.S.—*Geography*. Lord Prudhope.	W. C. Trevelyan, Capt. Portlock.—*Geography*. Capt. Washington.
1839. Birmingham	Rev. Dr. Buckland, F.R.S.—*Geography*. G.B.Greenough,F.R.S.	George Lloyd, M.D., H. E. Strickland, Charles Darwin.
1840. Glasgow ...	Charles Lyell, F.R.S.—*Geography*. G. B. Greenough, F.R.S.	W. J. Hamilton, D. Milne, Hugh Murray, H. E. Strickland, John Scoular, M.D.
1841. Plymouth ..	H. T. De la Beche, F.R.S.	W. J. Hamilton, Edward Moore, M.D., R. Hutton.
1842. Manchester	R. I. Murchison, F.R.S.	E. W. Binney, R. Hutton, Dr. R. Lloyd, H. E. Strickland.
1843. Cork	Richard E. Griffith, F.R.S., M.R.I.A.	Francis M. Jennings, H. E. Strickland.
1844. York	Henry Warburton, M.P., Pres. Geol. Soc.	Prof. Ansted, E. H. Bunbury.
1845. Cambridge .	Rev. Prof. Sedgwick, M.A., F.R.S.	Rev. J. C. Cumming, A. C. Ramsay, Rev. W. Thorp.
1846. Southampton	Leonard Horner, F.R.S.—*Geography*. G. B. Greenough, F.R.S.	Robert A. Austen, J. H. Norton, M.D., Prof. Oldham.—*Geography*. Dr. C. T. Beke.
1847. Oxford	Very Rev. Dr. Buckland, F.R.S.	Prof. Ansted, Prof. Oldham, A. C. Ramsay, J. Ruskin.
1848. Swansea ...	Sir H. T. De la Beche, C.B., F.R.S.	Starling Benson, Prof. Oldham, Prof. Ramsay.
1849. Birmingham	Sir Charles Lyell, F.R.S., F.G.S.	J. Beete Jukes, Prof. Oldham, Prof. A. C. Ramsay.
1850. Edinburgh *	Sir Roderick I. Murchison, F.R.S.	A. Keith Johnston, Hugh Miller, Professor Nicol.

SECTION C (*continued*).—GEOLOGY.

1851. Ipswich ...	William Hopkins, M.A., F.R.S...	C. J. F. Bunbury, G. W. Ormerod, Searles Wood.
1852. Belfast	Lieut.-Col. Portlock, R.E., F.R.S.	James Bryce, James MacAdam, Prof. M'Coy, Prof. Nicol.
1853. Hull	Prof. Sedgwick, F.R.S.	Prof. Harkness, William Lawton.
1854. Liverpool ..	Prof. Edward Forbes, F.R.S. ...	John Cunningham, Prof. Harkness, G. W. Ormerod, J. W. Woodall.
1855. Glasgow ...	Sir R. I. Murchison, F.R.S.	James Bryce, Prof. Harkness, Prof. Nicol.
1856. Cheltenham	Prof. A. C. Ramsay, F.R.S.	Rev. P. B. Brodie, Rev. R. Hepworth, Edward Hull, J. Scougall, T. Wright.
1857. Dublin	The Lord Talbot de Malahide ...	Prof. Harkness, Gilbert Sanders, Robert H. Scott.
1858. Leeds	William Hopkins, M.A., LL.D., F.R.S.	Prof. Nicol, H. C. Sorby, E. W. Shaw.
1859. Aberdeen ...	Sir Charles Lyell, LL.D., D.C.L., F.R.S.	Prof. Harkness, Rev. J. Longmuir, H. C. Sorby.
1860. Oxford	Rev. Prof. Sedgwick, LL.D., F.R.S., F.G.S.	Prof. Harkness, Edward Hull, Capt. Woodall.
1861. Manchester	Sir R. I. Murchison, D.C.L., LL.D., F.R.S., &c.	Prof. Harkness, Edward Hull, T. Rupert Jones, G. W. Ormerod.
1862. Cambridge	J. Beete Jukes, M.A., F.R.S.......	Lucas Barrett, Prof. T. Rupert Jones, H. C. Sorby.
1863. Newcastle ...	Prof. Warington W. Smyth, F.R.S., F.G.S.	E. F. Boyd, John Daglish, H. C. Sorby, Thomas Sopwith.

* At the Meeting of the General Committee held in Edinburgh, it was agreed "That the subject of Geography be separated from Geology and combined with Ethnology, to constitute a separate Section, under the title of the "Geographical and Ethnological Section," for Presidents and Secretaries of which see page xxxvi.

Date and Place.	Presidents.	Secretaries.
1864. Bath	Prof. J. Phillips, LL.D., F.R.S., F.G.S.	W. B. Dawkins, J. Johnston, H. C. Sorby, W. Pengelly.
1865. Birmingham	Sir R. I. Murchison, Bart.,K.C.B.	Rev. P. B. Brodie, J. Jones, Rev. E. Myers, H. C. Sorby, W. Pengelly.
1866. Nottingham	Prof.A.C.Ramsay, LL.D., F.R.S.	R. Etheridge, W. Pengelly, T. Wilson, G. H. Wright.
1867. Dundee......	Archibald Geikie, F.R.S., F.G.S.	Edward Hull, W. Pengelly, Henry Woodward.
1868. Norwich ...	R. A. C. Godwin-Austen, F.R.S., F.G.S.	Rev. O. Fisher, Rev. J. Gunn, W. Pengelly, Rev. H. H. Winwood.
1869. Exeter	Prof. R. Harkness, F.R.S., F.G.S.	W. Pengelly, W. Boyd Dawkins, Rev. H. H. Winwood.
1870. Liverpool...	Sir Philip de M. Grey Egerton, Bart., M.P., F.R.S.	W. Pengelly, Rev. H. H. Winwood, W. Boyd Dawkins, G. H. Morton.
1871. Edinburgh..	Prof. A. Geikie, F.R.S., F.G.S...	R. Etheridge, J. Geikie, J. McKenny Hughes, L. C. Miall.
1872. Brighton ...	R. A. C. Godwin-Austen, F.R.S.	L. C. Miall, George Scott, William Topley, Henry Woodward.

BIOLOGICAL SCIENCES.

COMMITTEE OF SCIENCES, IV.—ZOOLOGY, BOTANY, PHYSIOLOGY, ANATOMY.

1832. Oxford	Rev. P. B. Duncan, F.G.S.	Rev. Prof. J. S. Henslow.
1833. Cambridge*	Rev. W. L. P. Garnons, F.L.S....	C. C. Babington, D. Don.
1834. Edinburgh	Prof. Graham........................	W. Yarrell, Prof. Burnett.

SECTION D.—ZOOLOGY AND BOTANY.

1835. Dublin	Dr. Allman..........................	J. Curtis, Dr. Litton.
1836. Bristol	Rev. Prof. Henslow	J. Curtis, Prof. Don, Dr. Riley, S. Rootsey.
1837. Liverpool..	W. S. MacLeay	C. C. Babington, Rev. L. Jenyns, W. Swainson.
1838. Newcastle...	Sir W. Jardine, Bart..............	J. E. Gray, Prof. Jones, R. Owen, Dr. Richardson.
1839. Briminghan	Prof. Owen, F.R.S.	E. Forbes, W. Ick, R. Patterson.
1840. Glasgow ...	Sir W. J. Hooker, LL.D	Prof. W. Couper, E. Forbes, R. Patterson.
1841. Plymouth...	John Richardson, M.D., F.R.S..	J. Couch, Dr. Lankester, R. Patterson.
1842. Manchester	Hon. and Very Rev. W. Herbert, LL.D., F.L.S.	Dr. Lankester, R. Patterson, J. A. Turner.
1843. Cork	William Thompson, F.L.S.	G. J. Allman, Dr. Lankester, R. Patterson.
1844. York.........	Very Rev. The Dean of Manchester.	Prof. Allman, H. Goodsir, Dr. King, Dr. Lankester.
1845. Cambridge	Rev. Prof. Henslow, F.L.S.	Dr. Lankester, T. V. Wollaston.
1846. Southampton	Sir J. Richardson, M.D., F.R.S.	Dr. Lankester, T. V. Wollaston, H. Wooldridge.
1847. Oxford.......	H. E. Strickland, M.A., F.R.S....	Dr. Lankester, Dr. Melville, T. V. Wollaston.

SECTION D (*continued*).—ZOOLOGY AND BOTANY, INCLUDING PHYSIOLOGY.

[For the Presidents and Secretaries of the Anatomical and Physiological Subsections and the temporary Section E of Anatomy and Medicine, see pp. xxxvi.]

1848. Swansea ...	L. W. Dillwyn, F.R.S.	Dr. R. Wilbraham Falconer, A. Henfrey, Dr. Lankester.
1849. Birmingham	William Spence, F.R.S............	Dr. Lankester, Dr. Russell.
1850. Edinburgh..	Prof. Goodsir, F.R.S. L. & E. ...	Prof. J. H. Bennett, M.D., Dr. Lankester, Dr. Douglas Maclagan.

* At this Meeting Physiology and Anatomy were made a separate Committee, for Presidents and Secretaries of which see p. xxxv.

Date and Place.	Presidents.	Secretaries.
1851. Ipswich......	Rev. Prof. Henslow, M.A., F.R.S.	Prof. Allman, F. W. Johnston, Dr. E. Lankester.
1852. Belfast	W. Ogilby	Dr. Dickie, George C. Hyndman, Dr Edwin Lankester.
1853. Hull	C. C. Babington, M.A., F.R.S....	Robert Harrison, Dr. E. Lankester.
1854. Liverpool ...	Prof. Balfour, M.D., F.R.S.......	Isaac Byerley, Dr. E. Lankester.
1855. Glasgow ...	Rev. Dr. Fleeming, F.R.S.E. ...	William Keddie, Dr. Lankester.
1856. Cheltenham.	Thomas Bell, F.R.S., Pres.L.S....	Dr. J. Abercrombie, Prof. Buckman, Dr. Lankester.
1857. Dublin	Prof. W. H. Harvey, M.D., F.R.S.	Prof. J. R. Kinahan, Dr. E. Lankester, Robert Patterson, Dr. W. E. Steele.
1858. Leeds.........	C. C. Babington, M.A., F.R.S....	Henry Denny, Dr. Heaton, Dr. E. Lankester, Dr. E. Perceval Wright.
1859. Aberdeen ...	Sir W. Jardine, Bart., F.R.S.E..	Prof. Dickie, M.D., Dr. E. Lankester, Dr. Ogilvy.
1860. Oxford	Rev. Prof. Henslow, F.L.S.	W. S. Church, Dr. E. Lankester, P. L. Sclater, Dr. E. Perceval Wright.
1861. Manchester..	Prof. C. C. Babington, F.R.S....	Dr. T. Alcock, Dr. E. Lankester, Dr. P. L. Sclater, Dr. E. P. Wright.
1862. Cambridge...	Prof. Huxley, F.R.S.	Alfred Newton, Dr. E. P. Wright.
1863. Newcastle ...	Prof. Balfour, M.D., F.R.S.	Dr. E. Charlton, A. Newton, Rev. H. B. Tristram, Dr. E. P. Wright.
1864. Bath	Dr. John E. Gray, F.R.S.	H. B. Brady, C. E. Broom, H. T. Stainton, Dr. E. P. Wright.
1865. Birmingham	T. Thomson, M.D., F.R.S.	Dr. J. Anthony, Rev. C. Clarke, Rev. H. B. Tristram, Dr. E. P. Wright.
	SECTION D (*continued*).—BIOLOGY*.	
1866. Nottingham.	Prof. Huxley, LL.D., F.R.S.—*Physiological Dep.* Prof. Humphry, M.D., F.R.S.—*Anthropological Dep.* Alfred R. Wallace, F.R.G.S.	Dr. J. Beddard, W. Felkin, Rev. H. B. Tristram, W. Turner, E. B. Tylor, Dr. E. P. Wright.
1867. Dundee	Prof. Sharpey, M.D., Sec. R.S.—*Dep. of Zool. and Bot.* George Busk, M.D., F.R.S.	C. Spence Bate, Dr. S. Cobbold, Dr. M. Foster, H. T. Stainton, Rev. H. B. Tristram, Prof. W. Turner.
1868. Norwich ...	Rev. M. J. Berkeley, F.L.S.—*Dep. of Physiology.* W. H. Flower, F.R.S.	Dr. T. S. Cobbold, G. W. Firth, Dr. M. Foster, Prof. Lawson, H. T. Stainton, Rev. Dr. H. B. Tristram, Dr. E. P. Wright.
1869. Exeter	George Busk, F.R.S., F.L.S.—*Dep. of Bot. and Zool.* C. Spence Bate, F.R.S.—*Dep. of Ethno.* E. B. Tylor.	Dr. T. S. Cobbold, Prof. M. Foster, M.D., E. Ray Lankester, Professor Lawson, H. T. Stainton, Rev. H. B. Tristram.
1870. Liverpool...	Prof. G. Rolleston, M.A., M.D., F.R.S., F.L.S.—*Dep. Anat. and Physio.* Prof. M. Foster, M.D., F.L.S.—*Dep. of Ethno.* J. Evans, F.R.S.	Dr. T. S. Cobbold, Sebastian Evans, Prof. Lawson, Thos. J. Moore, H. T. Stainton, Rev. H. B. Tristram, C. Staniland Wake, E. Ray Lankester.
1871. Edinburgh	Prof. Allen Thomson, M.D., F.R.S.—*Dep. of Bot. and Zool.* Prof. Wyville Thomson, F.R.S.—*Dep. of Anthropo.* Prof. W. Turner, M.D.	Dr. T. R. Fraser, Dr. Arthur Gamgee, E. Ray Lankester, Prof. Lawson, H. T. Stainton, C. Staniland Wake, Dr. W. Rutherford, Dr. Kelburne King.
1872. Brighton ...	Sir John Lubbock, Bart., F.R.S.—*Dep. of Anat. and Physio.* Dr. Burdon Sanderson, F.R.S.—*Dep. of Anthropo.* Col. A. Lane Fox, F.G.S.	Prof. Thiselton-Dyer, H. T. Stainton, Prof. Lawson, F. W. Rudler, J. H. Lamprey, Dr. Gamgee, E. Ray Lankester, Dr. Pye Smith.

* At the Meeting of the General Committee at Birmingham, it was resolved:—"That the title of Section D be changed to Biology;" and "That for the word 'Subsection,' in the rules for conducting the business of the Sections, the word 'Department' be substituted.

Date and Place.	Presidents.	Secretaries.

ANATOMICAL AND PHYSIOLOGICAL SCIENCES.

COMMITTEE OF SCIENCES, V.—ANATOMY AND PHYSIOLOGY.

1833. Cambridge...	Dr. Haviland	Dr. Bond, Mr. Paget.
1834. Edinburgh...	Dr. Abercrombie	Dr. Roget, Dr. William Thomson.

SECTION E. (UNTIL 1847.)—ANATOMY AND MEDICINE.

1835. Dublin	Dr. Pritchard	Dr. Harrison, Dr. Hart.
1836. Bristol	Dr. Roget, F.R.S.	Dr. Symonds.
1837. Liverpool ...	Prof. W. Clark, M.D.	Dr. J. Carson, jun., James Long, Dr. J. R. W. Vose.
1838. Newcastle ...	T. E. Headlam, M.D.	T. M. Greenhow, Dr. J. R. W. Vose.
1839. Birmingham	John Yelloly, M.D., F.R.S.	Dr. G. O. Rees, F. Ryland.
1840. Glasgow ...	James Watson, M.D...............	Dr. J. Brown, Prof. Couper, Prof. Reid.
1841. Plymouth...	P. M. Roget, M.D., Sec.R.S. ...	Dr. J. Butter, J. Fuge, Dr. R. S. Sargent.
1842. Manchester.	Edward Holme, M.D., F.L.S. ...	Dr. Chaytor, Dr. R. S. Sargent.
1843. Cork.........	Sir James Pitcairn, M.D.........	Dr. John Popham, Dr. R. S. Sargent.
1844. York.........	J. C. Pritchard, M.D.	I. Erichsen, Dr. R. S. Sargent.

SECTION E.—PHYSIOLOGY.

1845. Cambridge .	Prof. J. Haviland, M.D.	Dr. R. S. Sargent, Dr. Webster.
1846. Southampton	Prof. Owen, M.D., F.R.S..........	C. P. Keele, Dr. Laycock, Dr. Sargent.
1847. Oxford* ...	Prof. Ogle, M.D., F.R.S..........	Dr. Thomas K. Chambers, W. P. Ormerod.

PHYSIOLOGICAL SUBSECTIONS OF SECTION D.

1850. Edinburgh	Prof. Bennett, M.D., F.R.S.E.	
1855. Glasgow ...	Prof. Allen Thomson, F.R.S. ...	Prof. J. H. Corbett, Dr. J. Struthers.
1857. Dublin	Prof. R. Harrison, M.D.	Dr. R. D. Lyons, Prof. Redfern.
1858. Leeds	Sir Benjamin Brodie, Bart., F.R.S.	C. G. Wheelhouse.
1859. Aberdeen ...	Prof. Sharpey, M.D., Sec.R.S. ...	Prof. Bennett, Prof. Redfern.
1860. Oxford	Prof. G. Rolleston, M.D., F.L.S.	Dr. R. M'Donnell, Dr. Edward Smith.
1861. Manchester.	Dr. John Davy, F.R.S.L. & E....	Dr. W. Roberts, Dr. Edward Smith.
1862. Cambridge .	C. E. Paget, M.D.	G. F. Helm, Dr. Edward Smith.
1863. Newcastle...	Prof. Rolleston, M.D., F.R.S. ...	Dr. D. Embleton, Dr. W. Turner.
1864. Bath	Dr. Edward Smith, LL.D., F.R.S.	J. S. Bartrum, Dr. W. Turner.
1865. Birminghm†.	Prof. Acland, M.D., LL.D., F.R.S.	Dr. A. Fleming, Dr. P. Heslop, Oliver Pembleton, Dr. W. Turner.

GEOGRAPHICAL AND ETHNOLOGICAL SCIENCES.

[For Presidents and Secretaries for Geography previous to 1851, see Section C, p. xxxii.]

ETHNOLOGICAL SUBSECTIONS OF SECTION D.

1846. Southampton	Dr. Pritchard	Dr. King.
1847. Oxford	Prof. H. H. Wilson, M.A.	Prof. Buckley.
1848. Swansea ...	....	G. Grant Francis.
1849. Birmingham	....	Dr. R. G. Latham.
1850. Edinburgh..	Vice-Admiral Sir A. Malcolm ...	Daniel Wilson.

* By direction of the General Committee at Oxford, Sections D and E were incorporated under the name of "Section D—Zoology and Botany, including Physiology" (see p. xxxiv). The Section being then vacant was assigned in 1851 to Geography.

† *Vide* note on preceding page.

Date and Place.	Presidents.	Secretaries.
	SECTION E.—GEOGRAPHY AND ETHNOLOGY.	
1851. Ipswich ...	Sir R. I. Murchison, F.R.S., Pres. R.G.S.	R. Cull, Rev. J. W. Donaldson, Dr. Norton Shaw.
1852. Belfast	Col. Chesney, R.A., D.C.L., F.R.S.	R. Cull, R. MacAdam, Dr. Norton Shaw.
1853. Hull	R. G. Latham, M.D., F.R.S. ...	R. Cull, Rev. H. W. Kemp, Dr. Norton Shaw.
1854. Liverpool...	Sir R. I. Murchison, D.C.L., F.R.S.	Richard Cull, Rev. H. Higgins, Dr. Ihne, Dr. Norton Shaw.
1855. Glasgow ...	Sir J. Richardson, M.D., F.R.S.	Dr. W. G. Blackie, R. Cull, Dr. Norton Shaw.
1856. Cheltenham	Col. Sir H. C. Rawlinson, K.C.B.	R. Cull, F. D. Hartland, W. H. Rumsey, Dr. Norton Shaw.
1857. Dublin	Rev. Dr. J. Henthawn Todd, Pres. R.I.A.	R. Cull, S. Ferguson, Dr. R. R. Madden, Dr. Norton Shaw.
1858. Leeds	Sir R. I. Murchison, G.C.St.S., F.R.S.	R. Cull, Francis Galton, P. O'Callaghan, Dr. Norton Shaw, Thomas Wright.
1859. Aberdeen ...	Rear-Admiral Sir James Clerk Ross, D.C.L., F.R.S.	Richard Cull, Professor Geddes, Dr. Norton Shaw.
1860. Oxford	Sir R. I. Murchison, D.C.L., F.R.S.	Capt. Burrows, Dr. J. Hunt, Dr. C. Lempriere, Dr. Norton Shaw.
1861. Manchester.	John Crawfurd, F.R.S.	Dr. J. Hunt, J. Kingsley, Dr. Norton Shaw, W. Spottiswoode.
1862. Cambridge .	Francis Galton, F.R.S.	J. W. Clarke, Rev. J. Glover, Dr. Hunt, Dr. Norton Shaw, T. Wright.
1863. Newcastle...	Sir R. I. Murchison, K.C.B., F.R.S.	C. Carter Blake, Hume Greenfield, C. R. Markham, R. S. Watson.
1864. Bath	Sir R. I. Murchison, K.C.B., F.R.S.	H. W. Bates, C. R. Markham, Capt. R. M. Murchison, T. Wright.
1865. Birmingham	Major-General Sir R. Rawlinson, M.P., K.C.B., F.R.S.	H. W. Bates, S. Evans, G. Jabet, C. R. Markham, Thomas Wright.
1866. Nottingham	Sir Charles Nicholson, Bart., LL.D.	H. W. Bates, Rev. E. T. Cusins, R. H. Major, Clements R. Markham, D. W. Nash, T. Wright.
1867. Dundee......	Sir Samuel Baker, F.R.G.S.	H. W. Bates, Cyril Graham, C. R. Markham, S. J. Mackie, R. Sturrock.
1868. Norwich ...	Capt. G. H. Richards, R.N., F.R.S.	T. Baines, H. W. Bates, C. R. Markham, T. Wright.
	SECTION E (*continued*).—GEOGRAPHY.	
1869. Exeter	Sir Bartle Frere, K.C.B., LL.D., F.R.G.S.	H. W. Bates, Clements R. Markham, J. H. Thomas.
1870. Liverpool...	Sir R. I. Murchison, Bt., K.C.B., LL.D., D.C.L., F.R.S., F.G.S.	H. W. Bates, David Buxton, Albert J. Mott, Clements R. Markham.
1871. Edinburgh.	Colonel Yule, C.B., F.R.G.S. ...	Clements R. Markham, A. Buchan, J. H. Thomas, A. Keith Johnston.
1872. Brighton ...	Francis Galton, F.R.S.	H. W. Bates, A. Keith Johnston, Rev. J. Newton, J. H. Thomas.

STATISTICAL SCIENCE.

	COMMITTEE OF SCIENCES, VI.—STATISTICS.	
1833. Cambridge .	Prof. Babbage, F.R.S.	J. E. Drinkwater.
1834. Edinburgh .	Sir Charles Lemon, Bart.	Dr. Cleland, C. Hope Maclean.
	SECTION F.—STATISTICS.	
1835. Dublin	Charles Babbage, F.R.S.	W. Greg, Prof. Longfield.
1836. Bristol	Sir Charles Lemon, Bart., F.R.S.	Rev. J. E. Bromby, C. B. Fripp, James Heywood.

Date and Place.	Presidents.	Secretaries.
1837. Liverpool...	Rt. Hon. Lord Sandon	W. R. Greg, W. Langton, Dr. W. C. Tayler.
1838. Newcastle...	Colonel Sykes, F.R.S.	W. Cargill, J. Heywood, W. R. Wood.
1839. Birmingham	Henry Hallam, F.R.S.	F. Clarke, R. W. Rawson, Dr. W. C. Tayler.
1840. Glasgow ...	Rt. Hon. Lord Sandon, F.R.S., M.P.	C. R. Baird, Prof. Ramsay, R. W. Rawson.
1841. Plymouth...	Lieut.-Col. Sykes, F.R.S.	Rev. Dr. Byrth, Rev. R. Luney, R. W. Rawson.
1842. Manchester.	G. W. Wood, M.P., F.L.S.	Rev. R. Luney, G. W. Ormerod, Dr. W. C. Tayler.
1843. Cork	Sir C. Lemon, Bart., M.P.	Dr. D. Bullen, Dr. W. Cooke Tayler.
1844. York.........	Lieut.-Col. Sykes, F.R.S., F.L.S.	J. Fletcher, J. Heywood, Dr. Laycock.
1845. Cambridge .	Rt. Hon. The Earl Fitzwilliam...	J. Fletcher, W. Cooke Tayler, LL.D.
1846. Southampton	G. R. Porter, F.R.S.	J. Fletcher, F. G. P. Neison, Dr. W. C. Tayler, Rev. T. L. Shapcott.
1847. Oxford	Travers Twiss, D.C.L., F.R.S. ...	Rev. W. H. Cox, J. J. Danson, F. G. P. Neison.
1848. Swansea ...	J. H. Vivian, M.P., F.R.S.	J. Fletcher, Capt. R. Shortrede
1849. Birmingham	Rt. Hon. Lord Lyttelton	Dr. Finch, Prof. Hancock, F. G. P. Neison.
1850. Edinburgh ..	Very Rev. Dr. John Lee, V.P.R.S.E.	Prof. Hancock, J. Fletcher, Dr. Stark.
1851. Ipswich......	Sir John P. Boileau, Bart.	J. Fletcher, Prof. Hancock.
1852. Belfast	His Grace the Archbishop of Dublin.	Prof. Hancock, Prof. Ingram, James MacAdam, Jun.
1853. Hull	James Heywood, M.P., F.R.S....	Edward Cheshire, William Newmarch.
1854. Liverpool ...	Thomas Tooke, F.R.S.	E. Cheshire, J. T. Danson, Dr. W. H. Duncan, W. Newmarch.
1855. Glasgow	R. Monckton Milnes, M.P.	J. A. Campbell, E. Cheshire, W. Newmarch, Prof. R. H. Walsh.

SECTION F (*continued*).—ECONOMIC SCIENCE AND STATISTICS.

1856. Cheltenham	Rt. Hon. Lord Stanley, M.P. ...	Rev. C. H. Bromby, E. Cheshire, Dr. W. N. Hancock Newmarch, W. M. Tartt.
1857. Dublin	His Grace the Archbishop of Dublin, M.R.I.A.	Prof. Cairns, Dr. H. D. Hutton, W. Newmarch.
1858. Leeds.........	Edward Baines	T. B. Baines, Prof. Cairns, S. Brown, Capt. Fishbourne, Dr. J. Strang.
1859. Aberdeen ...	Col. Sykes, M.P., F.R.S.	Prof. Cairns, Edmund Macrory, A. M. Smith, Dr. John Strang.
1860. Oxford	Nassau W. Senior, M.A.	Edmund Macrory, W. Newmarch, Rev. Prof. J. E. T. Rogers.
1861. Manchester	William Newmarch, F.R.S.	David Chadwick, Prof. R. C. Christie, E. Macrory, Rev. Prof. J. E. T. Rogers.
1862. Cambridge..	Edwin Chadwick, C.B.	H. D. Macleod, Edmund Macrory.
1863. Newcastle ...	William Tite, M.P., F.R.S.	T. Doubleday, Edmund Macrory, Frederick Purdy, James Potts.
1864. Bath.........	William Farr, M.D., D.C.L., F.R.S.	E. Macrory, E. T. Payne, F. Purdy.
1865. Birmingham	Rt. Hon. Lord Stanley, LL.D., M.P.	G. J. D. Goodman, G. J. Johnston, E. Macrory.
1866. Nottingham	Prof. J. E. T. Rogers...............	R. Birkin, Jun., Prof. Leone Levi, E. Macrory.
1867. Dundee......	M. E. Grant Duff, M.P.	Prof. Leone Levi, E. Macrory, A. J. Warden.
1868. Norwich ...	Samuel Brown, Pres. Instit. Actuaries.	Rev. W. C. Davie, Prof. Leone Levi.

Date and Place.	Presidents.	Secretaries.
1869. Exeter	Rt. Hon. Sir Stafford H. Northcote, Bart., C.B., M.P.	Edmund Macrory, Frederick Purdy, Charles T. D. Acland.
1870. Liverpool...	Prof. W. Stanley Jevons, M.A. ..	Chas. R. Dudley Baxter, E. Macrory, J. Miles Moss.
1871. Edinburgh	Rt. Hon. Lord Neaves............	J. G. Fitch, James Meikle.
1872. Brighton ...	Prof. Henry Fawcett, M.P.......	J. G. Fitch, Barclay Phillips.

MECHANICAL SCIENCE.

SECTION G.—MECHANICAL SCIENCE.

1836. Bristol	Davies Gilbert, D.C.L., F.R.S....	T. G. Bunt, G. T. Clark, W. West.
1837. Liverpool ...	Rev. Dr. Robinson	Charles Vignoles, Thomas Webster.
1838. Newcastle ...	Charles Babbage, F.R.S.	R. Hawthorn, C. Vignoles, T. Webster.
1839. Birmingham	Prof. Willis, F.R.S., and Robert Stephenson.	W. Carpmael, William Hawkes, Thomas Webster.
1840. Glasgow ...	Sir John Robinson..................	J. Scott Russell, J. Thomson, J. Tod, C. Vignoles.
1841. Plymouth...	John Taylor, F.R.S.	Henry Chatfield, Thomas Webster.
1842. Manchester .	Rev. Prof. Willis, F.R.S.	J. F. Bateman, J. Scott Russell, J. Thomson, Charles Vignoles.
1843. Cork	Prof. J. Macneill, M.R.I.A.......	James Thomson, Robert Mallet.
1844. York	John Taylor, F.R.S.	Charles Vignoles, Thomas Webster.
1845. Cambridge ..	George Rennie, F.R.S.	Rev. W. T. Kingsley.
1846. Southampton	Rev. Prof. Willis, M.A., F.R.S. .	William Betts, Jun., Charles Manby.
1847. Oxford	Rev. Prof. Walker, M.A., F.R.S.	J. Glynn, R. A. Le Mesurier.
1848. Swansea	Rev. Prof. Walker, M.A., F.R.S.	R. A. Le Mesurier, W. P. Struvé.
1849. Birmingham	Robert Stephenson, M.P., F.R.S.	Charles Manby, W. P. Marshall.
1850. Edinburgh ..	Rev. Dr. Robinson	Dr. Lees, David Stephenson.
1851. Ipswich......	William Cubitt, F.R.S............	John Head, Charles Manby.
1852. Belfast	John Walker, C.E., LL.D., F.R.S.	John F. Bateman, C. B. Hancock, Charles Manby, James Thomson.
1853. Hull	William Fairbairn, C.E., F.R.S..	James Oldham, J. Thomson, W. Sykes Ward.
1854. Liverpool ...	John Scott Russell, F.R.S.	John Grantham, J. Oldham, J. Thomson.
1855. Glasgow ...	W. J. Macquorn Rankine, C.E., F.R.S.	L. Hill, Jun., William Ramsay, J. Thomson.
1856. Cheltenham	George Rennie, F.R.S.	C. Atherton, B. Jones, Jun., H. M. Jeffery.
1857. Dublin	The Right Hon. The Earl of Rosse, F.R.S.	Prof. Downing, W. T. Doyne, A. Tate, James Thomson, Henry Wright.
1858. Leeds.........	William Fairbairn, F.R.S.	J. C. Dennis, J. Dixon, H. Wright.
1859. Aberdeen ...	Rev. Prof. Willis, M.A., F.R.S. .	R. Abernethy, P. Le Neve Foster, H. Wright.
1860. Oxford	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	P. Le Neve Foster, Rev. F. Harrison, Henry Wright.
1861. Manchester .	J. F. Bateman, C.E., F.R.S.......	P. Le Neve Foster, John Robinson, H. Wright.
1862. Cambridge ..	William Fairbairn, LL.D., F.R.S.	W. M. Fawcett, P. Le Neve Foster.
1863. Newcastle ...	Rev. Prof. Willis, M.A., F.R.S. .	P. Le Neve Foster, P. Westmacott, J. F. Spencer.
1864. Bath	J. Hawkshaw, F.R.S.	P. Le Neve Foster, Robert Pitt.
1865. Birmingham	Sir W. G. Armstrong, LL.D., F.R.S.	P. Le Neve Foster, Henry Lea, W. P. Marshall, Walter May.
1866. Nottingham	Thomas Hawksley, V.P.Inst. C.E., F.G.S.	P. Le Neve Foster, J. F. Iselin, M. A. Tarbottom.
1867. Dundee......	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	P. Le Neve Foster, John P. Smith, W. W. Urquhart.
1868. Norwich ...	G. P. Bidder, C.E., F.R.G.S. ...	P. Le Neve Foster, J. F. Iselin, C. Manby, W. Smith.

Date of Place.	Presidents.	Secretaries.
1869. Exeter	C. W. Siemens, F.R.S.	P. Le Neve Foster, H. Bauerman.
1870. Liverpool ...	Chas. B. Vignoles, C.E., F.R.S. .	H. Bauerman, P. Le Neve Foster, T. King, J. N. Shoolbred.
1871. Edinburgh	Prof. Fleeming Jenkin, F.R.S....	H. Bauerman, Alexander Leslie, J. P. Smith.
1872. Brighton ...	F. J. Bramwell, C.E................	H. M. Brunel, P. Le Neve Foster, J. G. Gamble, J. N. Shoolbred.

List of Evening Lectures.

Date and Place.	Lecturer.	Subject of Discourse.
1842. Manchester.	Charles Vignoles, F.R.S..........	The Principles and Construction of Atmospheric Railways.
	Sir M. I. Brunel	The Thames Tunnel.
	R. I. Murchison.	The Geology of Russia.
1843. Cork	Prof. Owen, M.D., F.R.S.	The Dinornis of New Zealand.
	Prof. E. Forbes, F.R.S.	The Distribution of Animal Life in the Ægean Sea.
	Dr. Robinson	The Earl of Rosse's Telescope.
1844. York	Charles Lyell, F.R.S.	Geology of North America.
	Dr. Falconer, F.R.S.	The Gigantic Tortoise of the Siwalik Hills in India.
1845. Cambridge ..	G. B. Airy, F.R.S., Astron. Royal	Progress of Terrestrial Magnetism.
	R. I. Murchison, F.R.S.........	Geology of Russia.
1846. Southampton	Prof. Owen, M.D., F.R.S.	Fossil Mammalia of the British Isles.
	Charles Lyell, F.R.S.	Valley and Delta of the Mississippi.
	W. R. Grove, F.R.S.	Properties of the Explosive substance discovered by Dr. Schönbein; also some Researches of his own on the Decomposition of Water by Heat.
1847. Oxford	Rev. Prof. B. Powell, F.R.S. ...	Shooting-stars.
	Prof. M. Faraday, F.R.S.	Magnetic and Diamagnetic Phenomena.
	Hugh E. Strickland, F.G.S. ...	The Dodo (*Didus ineptus*).[1]
1848. Swansea ...	John Percy, M.D., F.R.S.	Metallurgical operations of Swansea and its neighbourhood.
	W. Carpenter, M.D., F.R.S. ...	Recent Microscopical Discoveries.
1849. Birmingham	Dr. Faraday, F.R.S................	Mr. Gassiot's Battery.
	Rev. Prof. Willis, M.A., F.R.S.	Transit of different Weights with varying velocities on Railways.
1850. Edinburgh.	Prof. J. H. Bennett, M.D., F.R.S.E.	Passage of the Blood through the minute vessels of Animals in connexion with Nutrition.
	Dr. Mantell, F.R.S................	Extinct Birds of New Zealand.
1851. Ipswich......	Prof. R. Owen, M.D., F.R.S.	Distinction between Plants and Animals, and their changes of Form.
	G. B. Airy, F.R.S., Astron. Roy.	Total Solar Eclipse of July 28, 1851.
1852. Belfast	Prof. G.G. Stokes, D.C.L., F.R.S	Recent discoveries in the properties of Light.
	Colonel Portlock, R.E., F.R.S.	Recent discovery of Rock-salt at Carrickfergus, and geological and practical considerations connected with it.
1853. Hull	Prof. J. Phillips, LL.D., F.R.S., F.G.S.	Some peculiar phenomena in the Geology and Physical Geography of Yorkshire.
	Robert Hunt, F.R.S.	The present state of Photography.
1854. Liverpool ...	Prof. R. Owen, M.D., F.R.S....	Anthropomorphous Apes.
	Col. E. Sabine, V.P.R.S.	Progress of researches in Terrestrial Magnetism.

Date and Place.	Lecturer.	Subject of Discourse.
1855. Glasgow......	Dr. W. B. Carpenter, F.R.S. ...	Characters of Species.
	Lieut.-Col. H. Rawlinson	Assyrian and Babylonian Antiquities and Ethnology.
1856. Cheltenham	Col. Sir H. Rawlinson	Recent discoveries in Assyria and Babylonia, with the results of Cuneiform research up to the present time.
	W. R. Grove, F.R.S.	Correlation of Physical Forces.
1857. Dublin	Prof. W. Thomson, F.R.S.	The Atlantic Telegraph.
	Rev. Dr. Livingstone, D.C.L. ...	Recent discoveries in Africa.
1858. Leeds.........	Prof. J. Phillips, LL.D., F.R.S.	The Ironstones of Yorkshire.
	Prof. R. Owen, M.D., F.R.S. ...	The Fossil Mammalia of Australia.
1859. Aberdeen ...	Sir R. I. Murchison, D.C.L.	Geology of the Northern Highlands.
	Rev. Dr. Robinson, F.R.S.	Electrical Discharges in highly rarefied Media.
1860. Oxford	Rev. Prof. Walker, F.R.S.	Physical Constitution of the Sun.
	Captain Sherard Osborn, R.N. .	Arctic Discovery.
1861. Manchester .	Prof. W. A. Miller, M.A., F.R.S.	Spectrum Analysis.
	G. B. Airy, F.R.S., Astron. Roy. .	The late Eclipse of the Sun.
1862, Cambridge .	Prof. Tyndall, LL.D., F.R.S. ...	The Forms and Action of Water.
	Prof. Odling, F.R.S................	Organic Chemistry.
1863. Newcastle-on-Tyne.	Prof. Williamson, F.R.S.	The chemistry of the Galvanic Battery considered in relation to Dynamics.
	James Glaisher, F.R.S.	The Balloon Ascents made for the British Association.
1864. Bath	Prof. Roscoe, F.R.S...............	The Chemical Action of Light.
	Dr. Livingstone, F.R.S.	Recent Travels in Africa.
1865. Birmingham	J. Beete Jukes, F.R.S............	Probabilities as to the position and extent of the Coal-measures beneath the red rocks of the Midland Counties.
1866. Nottingham.	William Huggins, F.R.S..........	The results of Spectrum Analysis applied to Heavenly Bodies.
	Dr. J. D. Hooker, F.R.S..........	Insular Floras.
1867. Dundee......	Archibald Geikie, F.R.S..........	The Geological origin of the present Scenery of Scotland.
	Alexander Herschel, F.R.A.S....	The present state of knowledge regarding Meteors and Meteorites.
1868. Norwich	J. Fergusson, F.R.S.	Archæology of the early Buddhist Monuments.
	Dr. W. Odling, F.R.S.	Reverse Chemical Actions.
1869. Exeter	Prof. J. Phillips, LL.D., F.R.S.	Vesuvius.
	J. Norman Lockyer, F.R.S.......	The Physical Constitution of the Stars and Nebulæ.
1870. Liverpool ...	Prof. J. Tyndall, LL.D., F.R.S.	The Scientific Use of the Imagination.
	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	Stream-lines and Waves, in connexion with Naval Architecture.
1871. Edinburgh	F. A. Abel, F.R.S..................	On some recent investigations and applications of Explosive Agents.
	E. B. Tylor, F.R.S.	On the Relation of Primitive to Modern Civilization.
1872. Brighton ...	Prof. P. Martin Duncan, M.D., F.R.S.	Insect Metamorphosis.
	Prof. W. K. Clifford..............	The Aims and Instruments of Scientific Thought.

Date and Place.	Lecturer.	Subject of Discourse.

Lectures to the Operative Classes.

1867. Dundee......	Prof. J. Tyndall, LL.D., F.R.S.	Matter and Force.
1868. Norwich	Prof. Huxley, LL.D., F.R.S. ...	A piece of Chalk.
1869. Exeter	Prof. Miller, M.D., F.R.S.	Experimental illustrations of the modes of detecting the Composition of the Sun and other Heavenly Bodies by the Spectrum.
1870. Liverpool ...	Sir John Lubbock, Bart., M.P., F.R.S.	Savages.
1872. Brighton ...	William Spottiswoode, LL.D., F.R.S.	Sunshine, Sea, and Sky.

THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

THE GENERAL TREASURER'S ACCOUNT from 2nd August 1871 (commencement of EDINBURGH Meeting) to 14th August 187 (BRIGHTON).

RECEIPTS.

	£	s.	d.
To Balance brought from last Account	972	10	7
Received for Life Compositions at Edinburgh Meeting and since	389	0	0
" Annual Subscriptions, ditto ditto	743	0	0
" Associates' Tickets, ditto ditto	976	0	0
" Ladies' Tickets, ditto ditto	754	0	0
" Dividends on Stock	235	0	0
" for Sale of Publications	53	17	0
" Unexpended portion of Grant made to Dr. Matthiessen for carrying on researches in the Chemical Constitution of Cast Iron	31	1	7
	4154	9	2
" Government Eclipse-Expedition Account	53	12	9
	£4208	1	11

Examined and found correct.

J. GWYN JEFFREYS,
JOHN BALL,
A. LANE FOX,
Auditors.

PAYMENTS.

				£	s.	d.
Paid Expenses of Edinburgh Meeting, also Sundry Printing, Binding, Advertising, and Incidental Petty Expenses				420	19	6
" Printing, Engraving, &c. Report of 40th Meeting, Vol. XXXIX. (Liverpool)				576	6	7
" Printing on account of Report of 41st Meeting, Vol. XL. (Edinburgh)				43	10	0
" Salaries (1 year)				470	0	0
" Rent and Office Expenses (Albemarle Street)				120	15	0
" Grants made at Edinburgh Meeting, viz.—						
Maintaining Establishment of Kew Observatory	£300	0	0			
Metrical Committee	75	0	0			
Zoological Record	100	0	0			
Tidal Committee	200	0	0			
Committee on Carboniferous Corals	25	0	0			
" Organic Chemical Compounds	25	0	0			
" Exploration of Moab	100	0	0			
" Terato-Embryological Inquiries	10	0	0			
" Kent's Cavern Exploration	100	0	0			
" Luminous Meteors	20	0	0			
" Heat in the Blood	15	0	0			
" Fossil Crustacea	25	0	0			
" Fossil Elephants of Malta	25	0	0			
" Lunar Objects	20	0	0			
" Inverse Wave-Lengths	20	0	0			
" British Rainfall	100	0	0			
" Poisonous Substances Antagonism	10	0	0			
" Essential Oils, Chemical Constitution, &c.	40	0	0			
" Mathematical Tables	50	0	0			
" Thermal Conductivity of Metals	25	0	0			
				1285	0	0
" Committee on Treatment and Utilization of Sewage				401	9	3
				3318	0	4
1872. Aug. 14. Balance at London and Westminster Bank	£877	18	1			
" in hands of General Treasurer	12	3	6			
				890	1	7
				£4208	1	11

W. SPOTTISWOODE,
August 14, 1872.

Table showing the Attendance and Receipts

Date of Meeting.	Where held.	Presidents.	Old Life Members.	New Life Members.
1831, Sept. 27 ...	York	The Earl Fitzwilliam, D.C.L....	...	...
1832, June 19 ...	Oxford	The Rev. W. Buckland, F.R.S...	...	...
1833, June 25 ...	Cambridge	The Rev. A. Sedgwick, F.R.S....	...	...
1834, Sept. 8 ...	Edinburgh	Sir T. M. Brisbane, D.C.L.	...	...
1835, Aug. 10 ...	Dublin	The Rev. Provost Lloyd, LL.D.	...	...
1836, Aug. 22 ...	Bristol	The Marquis of Lansdowne	...	...
1837, Sept. 11 ...	Liverpool	The Earl of Burlington, F.R.S..	...	...
1838, Aug. 10 ...	Newcastle-on-Tyne..	The Duke of Northumberland...	...	...
1839, Aug. 26 ...	Birmingham	The Rev. W. Vernon Harcourt.	...	...
1840, Sept. 17 ...	Glasgow	The Marquis of Breadalbane ...	...	...
1841, July 20 ...	Plymouth	The Rev. W. Whewell, F.R.S....	169	65
1842, June 23 ...	Manchester	The Lord Francis Egerton	303	169
1843, Aug. 17 ...	Cork	The Earl of Rosse, F.R.S.	109	28
1844, Sept. 26 ...	York	The Rev. G. Peacock, D.D.	226	150
1845, June 19 ...	Cambridge	Sir John F. W. Herschel, Bart..	313	36
1846, Sept. 10 ...	Southampton	Sir Roderick I. Murchison, Bart.	241	10
1847, June 23 ...	Oxford	Sir Robert H. Inglis, Bart.	314	18
1848, Aug. 9	Swansea	The Marquis of Northampton...	149	3
1849, Sept. 12 ...	Birmingham	The Rev. T. R. Robinson, D.D..	227	12
1850, July 21 ...	Edinburgh	Sir David Brewster, K.H.	235	9
1851, July 2	Ipswich	G. B. Airy, Esq., Astron. Royal.	172	8
1852, Sept. 1 ...	Belfast	Lieut.-General Sabine, F.R.S....	164	10
1853, Sept. 3 ...	Hull	William Hopkins, Esq., F.R.S..	141	13
1854, Sept. 20 ...	Liverpool	The Earl of Harrowby, F.R.S...	238	23
1855, Sept. 12 ...	Glasgow	The Duke of Argyll, F.R.S.	194	33
1856, Aug. 6	Cheltenham	Prof. C. G. B. Daubeny, M.D....	182	14
1857, Aug. 26 ...	Dublin	The Rev. Humphrey Lloyd, D.D.	236	15
1858, Sept. 22 ...	Leeds	Richard Owen, M.D., D.C.L. ...	222	42
1859, Sept. 14 ...	Aberdeen	H.R.H. The Prince Consort ...	184	27
1860, June 27 ...	Oxford	The Lord Wrottesley, M.A.......	286	21
1861, Sept. 4 ...	Manchester	William Fairbairn, LL.D., F.R.S.	321	113
1862, Oct. 1	Cambridge	The Rev. Prof. Willis, M.A. ...	239	15
1863, Aug. 26 ...	Newcastle-on-Tyne..	Sir William G. Armstrong, C.B.	203	36
1864, Sept. 13 ...	Bath	Sir Charles Lyell, Bart., M.A....	287	40
1865, Sept. 6 ...	Birmingham	Prof. J. Phillips, M.A., LL.D....	292	44
1866, Aug. 22 ...	Nottingham	William R. Grove, Q.C., F.R.S.	207	31
1867, Sept. 4 ...	Dundee	The Duke of Buccleuch, K.C.B.	167	25
1868, Aug. 19 ...	Norwich	Dr. Joseph D. Hooker, F.R.S. .	196	18
1869, Aug. 18 ...	Exeter..................	Prof. G. G. Stokes, D.C.L.	204	21
1870, Sept. 14 ...	Liverpool	Prof. T. H. Huxley, LL.D.......	314	39
1871, Aug. 2	Edinburgh	Prof. Sir W. Thomson, LL.D....	246	28
1872, Aug. 14 ...	Brighton	Dr. W. B. Carpenter, F.R.S ...	245	36
1873, Sept. 17 ...	Bradford	J. P. Joule, D.C.L., F.R.S.......		

at Annual Meetings of the Association.

Attended by						Amount received during the Meeting.	Sums paid on Account of Grants for Scientific Purposes.
Old Annual Members.	New Annual Members.	Associates.	Ladies.	Foreigners.	Total.		
						£ s. d.	£ s. d.
...	...	...	...	...	353	....	....
...	...	...	...	...	...	....	....
...	...	...	...	...	900	....	....
...	...	...	...	...	1298	....	20 0 0
...	...	...	...	...	...	....	167 0 0
...	...	...	...	...	1350	....	434 14 0
...	...	...	...	...	1840	....	918 14 6
...	...	...	1100*	...	2400	....	956 12 2
...	...	...	...	34	1438	....	1595 11 0
...	...	...	...	40	1353	....	1546 16 4
46	317	...	60*	...	891	....	1235 10 11
75	376	33†	331*	28	1315	....	1449 17 8
71	185	...	160	...	...	....	1565 10 2
45	190	9†	260	...	...	....	981 12 8
94	22	407	172	35	1079	....	830 9 9
65	39	270	196	36	857	....	685 16 0
197	40	495	203	53	1260	....	208 5 4
54	25	376	197	15	929	707 0 0	275 1 8
93	33	447	237	22	1071	963 0 0	159 19 6
128	42	510	273	44	1241	1085 0 0	345 18 0
61	47	244	141	37	710	620 0 0	391 9 7
63	60	510	292	9	1108	1085 0 0	304 6 7
56	57	367	236	6	876	903 0 0	205 0 0
121	121	765	524	10	1802	1882 0 0	330 19 7
142	101	1094	543	26	2133	2311 0 0	480 16 4
104	48	412	346	9	1115	1098 0 0	734 13 9
156	120	900	569	26	2022	2015 0 0	507 15 3
111	91	710	509	13	1698	1931 0 0	618 18 2
125	179	1206	821	22	2564	2782 0 0	684 11 1
177	59	636	463	47	1689	1604 0 0	1241 7 0
184	125	1589	791	15	3139	3944 0 0	1111 5 10
150	57	433	242	25	1161	1089 0 0	1293 16 6
154	209	1704	1004	25	3335	3640 0 0	1608 3 10
182	103	1119	1058	13	2802	2965 0 0	1289 15 8
215	149	766	508	23	1997	2227 0 0	1591 7 10
218	105	960	771	11	2303	2469 0 0	1750 13 4
193	118	1163	771	7	2444	2613 0 0	1739 4 0
226	117	720	682	‡45	2004	2042 0 0	1940 0 0
229	107	678	600	17	1856	1931 0 0	1572 0 0
303	195	1103	910	14	2878	3096 0 0	1472 2 6
311	127	976	754	21	2463	2575 0 0	1285 0 0
280	80	937	912	43	2533	2649 0 0	

* Ladies were not admitted by purchased Tickets until 1843.
† Tickets for admission to Sections only. ‡ Including Ladies.

OFFICERS OF SECTIONAL COMMITTEES PRESENT AT THE BRIGHTON MEETING.

SECTION A.—MATHEMATICS AND PHYSICS.

President.—Warren De La Rue, D.C.L., Ph.D., F.R.S., V.P.R.A.S., V.P.C.S.
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Report of the Council for the Year 1871–72 *presented to the General Committee at Brighton, on Wednesday, August* 14*th,* 1872.

At each of their Meetings during the present year, the Council have received a Report from the General Treasurer, and his Report for the year will be laid before the General Committee this day.

The Council have to announce that a vacancy has occurred in the number of the Trustees in consequence of the death of Sir Roderick Murchison.

The Council take this opportunity of expressing their regret at the great loss which Science has sustained by his death. He worked long, earnestly, and with eminent success in the Sciences of Geology and Geography, and was at all times a steady patron of rising Scientific Men in all branches of Science. He was a Member and strenuous supporter of this Association at its first formation in 1831, and continued until the close of his life a very constant attendant at its Meetings and a firm promoter of its interests.

The Council recommend that Sir John Lubbock, Bart., be selected to fill the vacancy.

The list of Sectional Officers, which the Council will submit to the General Committee, has been arranged in accordance with the resolution of the General Committee at the Meeting at Edinburgh in 1871, viz. the Section of Biology has been divided into the three Departments of Anatomy and Physiology, Anthropology, and Zoology and Botany, and the Council have designated the Chairmen and Secretaries to take charge of the several Departments.

In accordance with the following resolution of the General Committee at Edinburgh, viz.:—

> That the President and General Officers, with power to add to their number, be requested to take such steps as may seem to them desirable in order to promote observations on the forthcoming Total Solar Eclipse,

a Committee was formed, consisting of the President, and General Officers of the Association, Professor J. C. Adams, Sir G. B. Airy, Astronomer Royal, Professor Clifton, Mr. De La Rue, Dr. Frankland, Mr. Hind, Mr. Lassell, President R.A.S., Lord Lindsay, Mr. Lockyer, General Sabine, General Strachey, Colonel Strange, and Professor Stokes; and a Letter was addressed by the President to the First Lord of the Treasury, requesting the Government to contribute £2000 towards the expenses of the Expedition, to afford to the Expedition the assistance of a Government Steamer to convey the parties composing it to the Stations for observation selected on the Coasts of Ceylon and India, and to obtain for the Expedition the cooperation of the Governor-General of India and of the Governor of Ceylon.

Her Majesty's Government acceded to the request contained in this letter. The Expedition was formed by the Committee, and proceeded to Ceylon and India in the charge of Mr. Lockyer and Dr. Thomson. The Governor-General of India and the Governor of Ceylon forwarded the objects of the Expedition by all means in their power.

The report of the proceedings and results of the Expedition will be presented to the Association by the Eclipse Committee in the usual course.

The Council have received a communication from the Royal Astronomical Society, informing them that that body contemplated printing, in a separate volume of their Transactions, the results of the observations of the Solar Eclipses of 1860 and 1870; and that, under these circumstances, they considered it would be advantageous to Science to publish, in the same manner, the results of the Observations made in 1871, under the auspices of the British Association; thus presenting a Record of all these Observations in one uniform Series.

The Council resolved to accept the proposal of the Council of the Royal Astronomical Society, and they appointed a Committee, consisting of Mr. Warren De La Rue, Colonel Strange, Dr. Huggins, and Mr. Lockyer, to arrange the necessary details with the Council of the Royal Astronomical Society.

There were five other resolutions referred to the Council for consideration or action, upon which the proceedings of the Council have been as follows:—

First Resolution.—"That the President and Council of the British Association be authorized to cooperate with the President and Council of the Royal Society, in whatever way may seem to them best, for the promotion of a Circumnavigation Expedition, specially fitted out to carry the Physical and Biological Exploration of the Deep Sea into all the Great Oceanic areas."

A copy of this Resolution was forwarded to the Royal Society, and a Committee was appointed, consisting of the President and Officers of the Association, Dr. Carpenter, Professor Huxley, Mr. Gwyn Jeffreys, Mr. C. W. Siemens, and Professor Williamson, and authorized to cooperate with the Committee of the Royal Society in carrying out the objects referred to in the Resolution. The Expedition has been organized, the ship 'Challenger' is being fitted out at Sheerness, Captain Nares has been appointed to the command, and Professor Wyville Thomson (who has obtained three years' leave of absence from the University of Edinburgh) is appointed to the Scientific charge, with an adequate Staff under him. It is hoped that the Expedition will sail about the end of November.

Second Resolution.—"1. That it is desirable that the British Association apply to the Treasury for Funds to enable the Tidal Committee to make observations and to continue their calculations.

"2. That it is desirable that the British Association should urge upon the Government of India the importance, for navigation and other practical purposes, and for science, of making accurate and continued observations on the Tides at several points on the coast of India."

The Council added General Strachey to the Committee on Tides. The Government of India, upon their application, have agreed to defray the expense of making Tidal observations in India, and of causing the experiments to be reduced according to the methods devised by the Committee on Tides.

In pursuance of the first part of this Resolution, the Committee on Tides being authorized by the Council to make an application to the Government, presented the following Memorial to the Lords Commissioners of H.M. Treasury:—

"*To the Right Honourable the Lords Commissioners of Her Majesty's Treasury, The Memorial of the British Association for the Advancement of Science.*

"HUMBLY SHEWETH,

"1. That in the year 1867 the British Association appointed a Committee 'for the purpose of promoting the extension, improvement, and harmonic analysis of tidal observations.' From that time until the present, under Committees reappointed from year to year, the proposed work has been carried on. The mode of procedure adopted, and the results obtained up to the month of August 1871, are fully stated in the accompanying series of printed reports.

"2. The primary object of the investigation is the advance of tidal science; but the Committee have uniformly kept in view the practical application of their results to Physical Geography, Meteorology, Coast and Harbour Engineering, and Navigation.

"3. A large mass of valuable observations recorded by self-registering tide-gauges during the last twenty years having been found available, the Committee have applied themselves in the first place to the reduction of these observations, and have deferred the object of promoting observations in other localities until the observations already made have been utilized to the utmost.

"4. The work thus undertaken has proved, as was anticipated, most laborious. The calculations have been performed, under the superintendence of Sir William Thomson, by skilled calculators recommended by the Nautical Almanac Office. The funds required to pay the calculators, and to print and prepare Tables, forms for calculation, &c., to the amount of £600, have been granted by the British Association in four successive annual allowances of £100 each, and a sum of £200 voted at the last Meeting. The last grant barely sufficed for the work actually in hand, and to secure the continuance of the investigation additional funds are necessary. The Council of the British Association therefore directed the Tidal Committee to make an application to the Government for assistance, the amount at present asked for being limited to £150.

"5. It seemed to the Council that after the Association had done so much in the way of actual expenditure of time by the Members of its Committee, and had given such a large contribution from its very limited funds, enough had been done to show the object to be one for which assistance may reasonably be expected from Government. On representations made by Colonel Walker, Director of the Trigonometrical Survey of India, the Indian Government has already granted the means of defraying the expense of making Tidal Observations in India, and applying to them the methods of reduction devised by the Committee of the British Association. The Council hope, therefore, that the Government of this country may be similarly disposed to assist in a matter of national importance.

(Signed) "WILLIAM THOMSON,
President of the British Association."

"May 21, 1872."

The Council regret to state that the application was rejected upon the grounds explained in the following letter:—

"Treasury Chambers,
3rd June, 1872.

"SIR,—The Chancellor of the Exchequer has referred to the Lords Commissioners of Her Majesty's Treasury the Memorial of the British Association

for the Advancement of Science, forwarded to him with your letter of 21st ultimo, praying for Government assistance in connexion with Tidal Observations.

"I am to state that their Lordships have given their anxious attention to the Memorial, and they are fully sensible of the interesting nature of such investigations, but that they feel that if they acceded to this request, it would be impossible to refuse to contribute towards the numerous other objects which men of eminence may desire to treat scientifically.

"Their Lordships must, therefore, though with regret, decline to make a promise of assistance towards the present object out of the public funds.

"I am, Sir,
"Your obedient Servant,
(Signed) "WILLIAM LAW."

"*Sir W. Thomson, Athenæum Club.*"

Third Resolution.—"That the Council of the Association be requested to take such steps as to them may seem most expedient in support of a proposal, made by Dr. Buys Ballot, to establish a telegraphic meteorological station at the Azores."

The Council appointed a Committee of their own body to report upon this proposal. The Committee after due deliberation reported that, while sympathizing with the proposal made by Dr. Buys Ballot, they cannot recommend a grant of money to be made by the Association for carrying it out. In this recommendation the Council concur.

Fourth Resolution.—"That the Council be requested to take into consideration the desirability of the publication of a periodic record of advances made in the various branches of science represented by the British Association."

The Council, after a careful consideration of this proposal, are not prepared to recommend the Association to undertake the publication of a periodic record of advances made in the various branches of science represented by the Sections of the British Association. They are of opinion that in so vast an undertaking special Societies should be invited to prepare such records, the action of the Association being limited to occasional grants in aid. They are of opinion, however, that the Association would do well to promote the more frequent publication in their Proceedings of critical reports on various branches of science, of the same nature as those which have already rendered previous volumes so valuable to investigators.

Fifth Resolution.—"1. That the Council of this Association be requested to take such steps as may appear to them desirable with reference to the arrangement now in contemplation to establish 'Leaving Examinations,' and to report to the Association on the present position of science-teaching in the public and first-grade schools.

"2. That the Council be requested to take such steps as they deem wisest in order to promote the introduction of scientific instruction into the elementary schools throughout the country."

A Committee, consisting of the President and the General Officers, Mr. G. Busk, Dr. Debus, Dr. Duncan, Mr. Fitch, Professor M. Foster, Mr. F. Galton, Dr. Hirst, Professor Huxley, Sir John Lubbock, Bart., Sir J. Paget, Bart., Rev. Professor Price, Professor Henry J. S. Smith, Professor Stokes, Professor Tyndall, and Professor Williamson, was appointed to consider the first of these resolutions, and to report on them to the Council.

In accordance with the recommendation of this Committee the Council adopted the following Resolution:—

That, having had under consideration the requests which the Committee of Masters of Schools have made to the Universities of Oxford and Cambridge upon points in which the Education of the Universities and Schools came into contact, the Council of the British Association recommend that Arithmetic, and either Elementary Physics or Chemistry experimentally treated, be introduced into the Leaving Examinations as compulsory subjects.

That the Head-Masters of Public Schools be requested to furnish the Council with information about the present position of Science-teaching in their Schools.

and the Council have communicated thereon with the Universities of Oxford and Cambridge, but at present no decision respecting "Leaving Examinations" has been arrived at in these Universities.

In accordance with the terms of the resolution passed by the General Committee last year, appointing a Committee on Science Lectures and Organization, the action proposed to be taken by this Committee in the following resolutions, was referred to the Council and sanctioned.

1. That a Subcommittee, consisting of Dr. Carpenter, Prof. Williamson, Prof. W. G. Adams, Dr. Hirst, Mr. Geo. Griffith, Dr. Michael Foster, and Prof. Roscoe be appointed for one year for the purpose of preparing a list of Lecturers for the consideration of this Committee, and of communicating with the various towns with the view of establishing a system of Science Lectures throughout the country.

2. That the names of the proposed Lecturers be selected (with their consent) from amongst the Members of the General Committee of the Association, or from amongst the Graduates of any University in the United Kingdom; and that the subjects upon which the Lectures be delivered shall be such as are included in one or other of the Sections of the Association.

The Committee have drawn up a Report, dealing generally with the subject of their inquiry, which the Council recommend should be referred to the Committee of Recommendations.

The Council have had under consideration the question of enabling Members, who are unable to be present at the Meetings, to obtain the Journal and other Printed Papers, and they have adopted a Regulation as follows:—

The Journal, President's Address, and other Printed Papers issued by the Association during the Annual Meeting will be forwarded daily to Members and others, on application and prepayment of 2*s*. 6*d*. to the Clerk of the Association, on or before the first day of the Meeting.

The Council regret to have to announce that the state of health of Dr. Thomas Thomson renders him unable to continue to act as one of the General Secretaries of the Association after the present Meeting. They cannot refrain from expressing their great regret at the loss of his valuable services.

The Council have agreed to recommend that Professor Michael Foster, F.R.S., be appointed one of the General Secretaries in his place, and his name will be proposed to the General Committee at the Meeting for the Election of the Council and Officers on Monday next.

The Council have added the following names of gentlemen, present

at the last Meeting of the Association, to the list of Corresponding Members, viz.:—

His Imperial Majesty the Emperor of the Brazils.
Professor Dr. Colding.
Dr. Güssfeldt.
Dr. Lüroth.
Dr. Lütken.
Dr. Joseph Szabó.

The General Committee are reminded that Bradford has been selected as the place of meeting for next year. Invitations for subsequent Meetings have been received from Belfast and Glasgow.

Recommendations adopted by the General Committee at the Brighton Meeting in August 1872.

[When Committees are appointed, the Member first named is regarded as the Secretary, except there is a specific nomination.]

Involving Grants of Money.

That the Committee, consisting of Professor Cayley, Professor Stokes, Professor H. J. S. Smith, Sir W. Thomson, and Mr. J. W. L. Glaisher (Secretary), on Mathematical Tables be reappointed, with a grant of £100 for the calculation and printing of numerical tables.

That the Committee on Tides, consisting of Sir W. Thomson, Professor J. C. Adams, Professor W. J. M. Rankine, Mr. J. Oldham, Rear-Admiral Richards, General Strachey, Mr. W. Parkes, and Colonel Walker, be reappointed, with a grant of £400 to complete the reduction of Tidal Observations from existing data, and that an urgent recommendation be made to the Government to undertake Tidal Observations and their reduction.

That the Committee for reporting on the Rainfall of the British Isles be reappointed, and that this Committee consist of Mr. Charles Brooke, Mr. Glaisher, Professor Phillips, Mr. G. J. Symons, Mr. J. F. Bateman, Mr. R. W. Mylne, Mr. T. Hawksley, Professor J. C. Adams, Mr. C. Tomlinson, Professor Sylvester, Dr. Pole, Mr. Rogers Field, Professor Ansted, and Mr. Buchan; that Mr. G. J. Symons be the Secretary, and that the sum of £100 be placed at their disposal for the purpose.

That the Committee on Underground Temperature, consisting of Professor Everett (Secretary), Sir W. Thomson, Sir Charles Lyell, Bart., Professor J. Clerk Maxwell, Professor Phillips, Mr. G. J. Symons, Professor Ramsay, Professor Geikie, Mr. Glaisher, Rev. Dr. Graham, Mr. George Maw, Mr. Pengelly, Mr. S. J. Mackie, Professor Edward Hull, and Professor Ansted, be reappointed; that Mr. Joseph Prestwich be added to the Committee, and that the sum of £150 (£100 being a grant already made which has lapsed) be placed at their disposal for the purpose.

That a grant of £50 having been made for the Calculation of the Gaussian Constants, and only £40 having been drawn by the late Chairman Sir J. Herschel, the remaining £10 be regranted to Mr. G. Griffith and Professor Erman for expenses already incurred.

That the Committee on Luminous Meteors, consisting of Mr. Glaisher, Mr. R. P. Greg, Professor A. S. Herschel, be reappointed, with a grant of £30 for projecting and reducing upon suitable maps the observations of meteors

collected during the last few years by the Committee, so as to show their radiant points.

That Mr. Glaisher, Col. Strange, Sir W. Thomson, Mr. Brooke, Mr. Walker, Dr. Mann, and M. de Fonvielle be a Committee for the purpose of investigating the efficacy of Lightning-conductors, giving suggestions for their improvement, and reporting upon any case in which a building has been injured by lightning, especially where such building was professedly protected by a lightning-conductor, and that the sum of £50 be placed at their disposal for the purpose.

That Professor A. W. Williamson, Sir W. Thomson, Professor Clerk Maxwell, Professor G. C. Foster, Mr. Abel, Professor F. Jenkin, Mr. Siemens, and Mr. R. Sabine be reappointed a Committee for the purpose of testing the New Pyrometer of Mr. Siemens, and that the sum of £30 be placed at their disposal for the purpose.

That the Committee, consisting of Dr. Huggins, Mr. J. N. Lockyer, Dr. Reynolds, Professor Swan, and Mr. Stoney, on Inverse Wave-lengths be reappointed, and that the sum of £150 be placed at their disposal.

That the Committee on the Thermal Conductivity of Metals, consisting of Professor Tait, Professor Tyndall, and Professor Balfour Stewart, be reappointed, and that the sum of £50 be placed at their disposal for the purpose.

That Professor Williamson, Professor Roscoe, and Professor Frankland be a Committee for the purpose of superintending the Monthly Records of the Progress of Chemistry published in the Journal of the Chemical Society, and that the sum of £200 (last year's grant of £100 was not drawn) be placed at their disposal for the purpose.

That Dr. Gladstone, Dr. C. R. A. Wright, and Mr. Chandler Roberts be reappointed a Committee for the purpose of investigating the chemical constitution and optical properties of essential oils; that Mr. Chandler Roberts be the Secretary, and that the sum of £30 be placed at their disposal for the purpose.

That Dr. Crum Brown, Mr. Dewar, Dr. Gladstone, Dr. Williamson, Sir W. Thomson, and Professor Tait be a Committee for the purpose of determining the temperatures of incandescent bodies by the refrangibility of the light they emit, and that the sum of £50 be placed at their disposal for the purpose.

That Dr. Crum Brown, Professor Tait, and Mr. Dewar be a Committee for the purpose of investigating the Electric Tensions of galvanic cells in which the oxides or acids of chlorine or iodine form the liquid elements, and that the sum of £25 be placed at their disposal for the purpose.

That Professor Ramsay, Professor Geikie, Professor J. Young, Professor Nicol, Dr. Bryce, Dr. Arthur Mitchell, Professor Hull, Sir R. Griffith, Bart., Dr. King, Professor Harkness, Mr. Prestwich, Mr. Hughes, Rev. H. W. Crosskey, Mr. W. Jolly, Mr. D. Milne Home, and Mr. Pengelly be reappointed a Committee for the purpose of ascertaining the existence in different parts of the United Kingdom of any Erratic Blocks or Boulders, indicating on Maps their position and height above the sea, as also of ascertaining the nature of the rocks composing these blocks, their size, shape, and other particulars of interest, and of endeavouring to prevent the destruction of such blocks as in the opinion of the Committee are worthy of being preserved; that the Rev. H. W. Crosskey be the Secretary, and that the sum of £10 be placed at their disposal for the purpose.

That Sir C. Lyell, Bart., Professor Phillips, Sir J. Lubbock, Bart., Mr.

J. Evans, Mr. E. Vivian, Mr. W. Pengelly, Mr. G. Busk, Mr. W. B. Dawkins, and Mr. W. A. Sandford be a Committee for the purpose of continuing the Exploration of Kent's Cavern, Torquay; that Mr. Pengelly be the Secretary, and that the sum of £150 be placed at their disposal for the purpose.

That Sir J. Lubbock, Bart., Professor Phillips, Messrs. W. Boyd Dawkins, and T. McKenny Hughes, be a Committee for the purpose of carrying out the exploration of the Settle Cave; that Mr. W. Boyd Dawkins be the Secretary, and that the sum of £50 be placed at their disposal for the purpose.

That Mr. G. Busk, Dr. Leith Adams, and Mr. Boyd Dawkins be reappointed a Committee for the purpose of illustrating by plates an account of the Fossil Elephants of Malta; that Dr. Leith Adams be the Secretary, and that the sum of £25 be placed at their disposal for the purpose.

That Professor Harkness, Mr. James Thomson, Dr. Duncan, and Mr. Thomas Davidson be reappointed a Committee for the purpose of continuing the investigation of Carboniferous Corals with the view of reproducing them for publication; that Mr. Thomson be the Secretary, and that the sum of £25 be placed at their disposal for the purpose.

That Mr. Carruthers, Mr. W. H. Baily, Professor Harkness, and Professor Hull be a Committee for the purpose of investigating the Fossil Flora of Ireland; that Mr. W. H. Baily be the Secretary, and that the sum of £20 be placed at their disposal for the purpose.

That Professor Harkness, Mr. W. Jolly, and Dr. J. Bryce be a Committee for the purpose of collecting Fossils from localities of difficult access in North-western Scotland, that the specimens be deposited in the Edinburgh Industrial Museum, and that duplicates be deposited in such Museums as the authorities of the Association may designate; that Mr. William Jolly be the Secretary, and that the sum of £10 be placed at their disposal for the purpose.

That Dr. Bryce, Sir W. Thomson, Mr. J. Brough, Mr. G. Forbes, Mr. D. Milne Home, and Mr. James Thomson be a Committee for the purpose of continuing the observations and records of Earthquakes in Scotland; that Dr. Bryce be the Secretary, and that the sum of £20 be placed at their disposal for the purpose.

That Messrs. H. Willett, Godwin-Austen, W. Topley, T. Davidson, J. Prestwich, W. Boyd Dawkins, and H. Woodward be a Committee for the purpose of promoting the "Sub-Wealden exploration;" that Mr. Henry Willett be the Secretary, and that the sum of £25 be placed at their disposal for the purpose.

That Colonel Lane Fox, Dr. Beddoe, Mr. Franks, Mr. Francis Galton, Mr. E. W. Brabrook, Sir J. Lubbock, Bart., Sir Walter Elliot, Mr. Clements R. Markham, and Mr. E. B. Tylor be a Committee for the purpose of preparing and publishing brief forms of instruction for travellers, ethnologists, and other anthropological observers; that Colonel Lane Fox be the Secretary, and that the sum of £25 be placed at their disposal for the purpose.

That Mr. Stainton, Professor Newton, and Sir John Lubbock, Bart., be reappointed a Committee for the purpose of continuing a Record of Zoological Literature; that Mr. Stainton be the Secretary, and that the sum of £100 be placed at their disposal for the purpose.

That Professor Sir Robert Christison, Bart., Dr. Laycock, and Dr. Fraser be a Committee for the purpose of investigating the antagonism of the action of poisonous substances; that Dr. Fraser be the Secretary, and that the sum of £20 be placed at their disposal for the purpose.

That Professor Balfour, Dr. Cleghorn, Mr. Robert Hutchinson, Mr. Buchan,

and Mr. Sadler be reappointed a Committee for the purpose of taking observations on the effect of the denudation of timber on the rainfall of North Britain; that Mr. Hutchinson be the Secretary, and that the sum of £20 be placed at their disposal for the purpose, the grant made last year not having been drawn.

That the Committee for the purpose of continuing the investigations on the Treatment and Utilization of Sewage be renewed, and that such Committee consist of Mr. R. B. Grantham, Professor Corfield, Mr. J. Bailey Denton, Mr. Bramwell, Dr. J. H. Gilbert, Mr. W. Hope, Dr. A. Voelcker, Professor Williamson, and Professor Way, and that the sum of £100 be placed at their disposal for the purpose.

That the Committee, consisting of Mr. Froude, Professor W. J. Macquorn Rankine, Mr. C. W. Merrifield, Mr. C. W. Siemens, Mr. Bramwell, Mr. A. E. Fletcher, the Rev J. Berthon, Mr. Shoolbred, Mr. James R. Napier, and Mr. W. Smith previously appointed for measuring the speed of ships by means of the difference of the height of two columns of liquid, be requested to report generally on the subject of instruments for testing the speed of ships, and that they be requested to present a separate report on the special class of instruments therein referred to them; that the sum of £50 be placed at their disposal for the purpose, and that Mr. J. Shoolbred be the Secretary.

Applications for Reports and Researches not involving Grants of Money.

That the Committee, consisting of Dr. Joule, Sir W. Thomson, Professor Tait, Professor Balfour Stewart, and Professor J. C. Maxwell, be reappointed to effect the determination of the Mechanical Equivalent of Heat.

That the Eclipse Committee, consisting of the President and General Officers (with power to add to their number), be reappointed.

That Sir W. Thomson, Professor Everett, Professor G. C. Foster, Professor J. C. Maxwell, Mr. G. J. Stoney, Professor Fleeming Jenkin, Professor Rankine, Dr. Siemens, and Mr. Bramwell be a Committee for reporting on the Nomenclature of Dynamical and Electrical Units, and that Professor Everett be the Secretary.

That Professor Sylvester, Professor Cayley, Professor Hirst, Rev. Professor Bartholomew Price, Professor H. J. S. Smith, Dr. Spottiswoode, Mr. R. B. Hayward, Dr. Salmon, Rev. R. Townsend, Professor Fuller, Professor Kelland, Mr. J. M. Wilson, and Professor Clifford be reappointed a Committee (with power to add to their number) for the purpose of considering the possibility of improving the methods of instruction in elementary geometry; and that Professor Clifford be the Secretary.

That Mr. W. H. L. Russell be requested to continue his Report on recent progress in the theory of Elliptic and Hyperelliptic Functions.

That Professor Tait be requested to prepare a Report on Quaternions.

That the Committee, consisting of the following Members, with power to add to their number,—Professor Roscoe, Professor W. G. Adams, Professor Andrews, Professor Balfour, Mr. Baxendell, Mr. Bramwell, Professor A. Crum Brown, Mr. Buchan, Dr. Carpenter, Professor Core, Dr. De La Rue, Professor Thiselton Dyer, Sir Walter Elliot, Professor M. Foster, Professor Flower, Professor G. C. Foster, Professor Geikie, Dr. J. H. Gladstone, Mr. Griffith, Rev. R. Harley, Dr. Hirst, Dr. Hooker, Dr. Huggins, Professor Huxley, Professor Fleeming Jenkin, Dr. Joule, Colonel Lane Fox, Dr. Lankester, Mr. J. N. Lockyer, Professor Clerk Maxwell, Mr. D. Milne-Home, Dr. O'Callaghan, Dr. Odling, Professor Ramsay, Dr. Spottiswoode, Professor Balfour Stewart,

Mr. Stainton, Professor Tait, Mr. J. A. Tinné, Dr. Allen Thomson, Sir William Thomson, Professor Wyville Thomson, Professor Turner, Colonel Strange, Professor A. W. Williamson, Mr. G. V. Vernon, Dr. Young; and that Professor Roscoe be the Secretary,—be reappointed—

1°, to consider and report on the best means of advancing science by Lectures, with authority to act, subject to the approval of the Council, in the course of the present year, if judged desirable.

2°, to consider and report whether any steps can be taken to render scientific organization more complete and effectual.

That Mr. Roberts, Dr. Mills, Dr. Stenhouse, Dr. Boycott, and Mr. Gadesden be a Committee for the purpose of inquiring into the method of making gold assays, and stating the results thereof; that Mr. W. C. Roberts be the Secretary.

That Professor Phillips, Professor Harkness, Mr. Henry Woodward, Mr. James Thomson, and Mr. L. C. Miall be a Committee for the purpose of investigating and reporting upon the Labyrinthodonts of the Coal-measures; and that Mr. L. C. Miall be the Secretary.

That the Rev. Canon Tristram, Professor Newton, Mr. H. E. Dresser, Mr. J. E. Harting, and the Rev. H. F. Barnes, with the addition of Mr. Harland of Bridlington, and Mr. Monk of Lewes, be appointed a Committee for the purpose of continuing the investigation on the desirability of establishing "a close time" for the preservation of indigenous animals; that Mr. H. E. Dresser be the Secretary.

That Dr. Rolleston, Dr. Sclater, Dr. Anton Dohrn, Professor Huxley, Professor Wyville Thomson, and Mr. E. Ray Lankester be reappointed a Committee for the purpose of promoting the foundation of Zoological Stations; that Dr. Anton Dohrn be the Secretary.

That Dr. Arthur Gamgee, Mr. E. Ray Lankester, and Professor M. Foster be a Committee for the purpose of investigating the amount of Heat generated in the Blood in the process of Arterialization; that Dr. Gamgee be the Secretary.

That Mr. Carruthers, Dr. Hooker, Professor Balfour, and Professor Thiselton Dyer be reappointed a Committee for the purpose of investigating the Fossil Flora of Britain; that Mr. Carruthers be the Secretary.

That the Metric Committee be reappointed, such Committee to consist of Sir John Bowring, The Right Hon. Sir Stafford H. Northcote, Bart., C.B., M.P., The Right Hon. C. B. Adderley, M.P., Mr. Samuel Brown, Dr. Farr, Mr. Frank P. Fellowes, Professor Frankland, Mr. James Heywood, Professor Leone Levi, Mr. C. W. Siemens, Professor A. W. Williamson, Dr. George Glover, Sir Joseph Whitworth, Bart., Mr. J. R. Napier, Mr. J. V. N. Bazalgette, and Sir W. Fairbairn, Bart.; that Professor Leone Levi be the Secretary.

That Professor Cayley, Mr. J. W. L. Glaisher, Dr. W. Pole, Mr. Merrifield, Professor Fuller, Mr. H. M. Brunel, and Professor W. R. Clifford be a Committee to estimate the cost of constructing Mr. Babbage's Analytical Engine, and to consider the advisability of printing tables by its means.

That a Committee, consisting of Mr. Francis Galton, Mr. W. Froude, Mr. C. W. Merrifield, and Professor Rankine, be appointed to consider and report on Machinery for obtaining a record of the roughness of the Sea and Measurement of Waves near shore.

That Sir Henry Rawlinson, Mr. Francis Galton, Admiral Ommanney, Mr. Hawkshaw, Mr. Bramwell, Mr. De La Rue, and Mr. Godwin-Austen be a Committee (with power to add to their number) for the purpose of representing to the Government the advisability of an issue of the one-inch Ordnance Maps, printed on strong thin paper, each sheet having a portion of an index map impressed on the outside, to show its contents and those of the adjacent sheets and their numbers. Also that these maps should be sold in all important towns and, if possible, at the several Post-offices; that Mr. Francis Galton be the Secretary.

Resolutions referred to the Council for consideration and action if it seem desirable.

That the Council be requested to take such steps as they deem desirable to induce the Colonial Office to afford sufficient aid to the Observatory at Mauritius to enable an investigation of the Cyclones of the Pacific Ocean to be carried on there.

That, in the event of the Council having reason to believe that any changes affecting the acknowledged efficiency and scientific character of the Botanical Establishment at Kew are contemplated by the Government, the Council be requested to take such steps as in their judgment will be conducive to the interests of Botanical science in this country.

That the Council be requested to take such steps as they may deem desirable "to urge upon the Indian Government the preparation of a Photoheliograph and other instruments for solar observation, with the view of assisting in the observation of the Transit of Venus in 1874, and for the continuation of solar observations in India."

Communications ordered to be printed in extenso *in the Annual Report of the Association.*

That M. Hermite's paper, "Sur l'élimination des fonctions arbitraires," be printed *in extenso* among the Reports.

That the Tabulated List of species given in Mr. J. Gwyn Jeffreys's paper on the correlation of the European and North-American Mollusca be printed in the Reports of the Association.

That Mr. Froude's paper "On the Frictional Resistance of Surfaces immersed in Fluids" be printed *in extenso* in the Transactions, with the illustrations.

That Mr. Easton's paper on the Brighton Waterworks be printed *in extenso* in the Transactions.

That Mr. Bramwell's paper on Amsler's Planimeter be printed *in extenso* in the Transactions.

Synopsis of Grants of Money appropriated to Scientific Purposes by the General Committee at the Brighton Meeting in August 1872. The names of the Members who would be entitled to call on the General Treasurer for the respective Grants are prefixed.

Mathematics and Physics.

	£	s.	d.
*Cayley, Professor.—Mathematical Tables	100	0	0
*Thomson, Professor Sir W.—Tidal Observations	400	0	0
*Brooke, Mr.—British Rainfall	100	0	0
*Everett, Prof.—Underground Temperature (£100 renewed)	150	0	0
*Griffith, Mr. G.—Gaussian Constants (renewed)	10	0	0
*Glaisher, Mr. J.—Luminous Meteors	30	0	0
Glaisher, Mr. J.—Efficacy of Lightning Conductors	50	0	0
*Williamson, Prof. A. W.—Testing Siemens's New Pyrometer (renewed)	30	0	0
*Huggins, Dr. W.—Tables of Inverse Wave-lengths	150	0	0
*Tait, Professor.—Thermal Conductivity of Metals	50	0	0

Chemistry.

	£	s.	d.
*Williamson, Prof. A. W.—Records of the Progress of Chemistry (£100 renewed)	200	0	0
*Gladstone, Dr.—Chemical Constitution and Optical Properties of Essential Oils	30	0	0
Brown, Professor Crum.—Temperature of Incandescent Bodies	50	0	0
Brown, Professor Crum.—Electric Tensions of Batteries	25	0	0

Geology.

	£	s.	d.
*Ramsay, Professor.—Mapping Positions of Erratic Blocks and Boulders (renewed)	10	0	0
*Lyell, Sir C., Bart.—Kent's Cavern Exploration	150	0	0
Lubbock, Sir J.—Exploration of Settle Cave	50	0	0
*Busk, Mr.—Fossil Elephants of Malta	25	0	0
*Harkness, Professor.—Investigation of Fossil Corals	25	0	0
Carruthers, Mr.—Fossil Flora of Ireland	20	0	0
*Harkness, Professor.—Collection of Fossils in the North-West of Scotland	10	0	0
*Bryce, Dr.—Earthquakes in Scotland	20	0	0
Willett, Mr. H.—The Sub-Wealden Exploration	25	0	0
Carried forward	£1710	0	0

* Reappointed.

Biology.

Brought forward	£1710	0	0
Lane Fox, Col. A.—Forms of Instruction for Travellers	25	0	0
*Stainton, Mr.—Record of the Progress of Zoology..........	100	0	0
*Christison, Sir R.—Antagonism of the Action of Poisons	20	0	0
*Balfour, Professor.—Effect of the Denudation of Timber on the Rainfall in North Britain (renewed)	20	0	0

Mechanics.

*Grantham, Mr. R. B.—Treatment and Utilization of Sewage	100	0	0
*Froude, Mr. W.—Experiments on Instruments for Measuring the Speed of Ships and Currents (£30 renewed)	50	0	0
Total....	£2025	0	0

* Reappointed.

Place of Meeting in 1874.

It was resolved that the Annual Meeting of the Association in 1874 be held at Belfast.

General Statement of Sums which have been paid on Account of Grants for Scientific Purposes.

	£	s.	d.
1834.			
Tide Discussions	20	0	0
1835.			
Tide Discussions	62	0	0
British Fossil Ichthyology	105	0	0
	£167	0	0
1836.			
Tide Discussions	163	0	0
British Fossil Ichthyology	105	0	0
Thermometric Observations, &c.	50	0	0
Experiments on long-continued Heat	17	1	0
Rain-Gauges	9	13	0
Refraction Experiments	15	0	0
Lunar Nutation	60	0	0
Thermometers	15	6	0
	£434	14	0
1837.			
Tide Discussions	284	1	0
Chemical Constants	24	13	6
Lunar Nutation	70	0	0
Observations on Waves	100	12	0
Tides at Bristol	150	0	0
Meteorology and Subterranean Temperature	89	5	0
Vitrification Experiments	150	0	0
Heart Experiments	8	4	6
Barometric Observations	30	0	0
Barometers	11	18	6
	£918	14	6
1838.			
Tide Discussions	29	0	0
British Fossil Fishes	100	0	0
Meteorological Observations and Anemometer (construction)	100	0	0
Cast Iron (Strength of)	60	0	0
Animal and Vegetable Substances (Preservation of)	19	1	10
Railway Constants	41	12	10
Bristol Tides	50	0	0
Growth of Plants	75	0	0
Mud in Rivers	3	6	6
Education Committee	50	0	0
Heart Experiments	5	3	0
Land and Sea Level	267	8	7
Subterranean Temperature	8	6	0
Steam-vessels	100	0	0
Meteorological Committee	31	9	5
Thermometers	16	4	0
	£956	12	2
1839.			
Fossil Ichthyology	110	0	0
Meteorological Observations at Plymouth	63	10	0
Mechanism of Waves	144	2	0
Bristol Tides	35	18	6
Meteorology and Subterranean Temperature	21	11	0
Vitrification Experiments	9	4	7
Cast-Iron Experiments	100	0	0
Railway Constants	28	7	2
Land and Sea Level	274	1	4
Steam-vessels' Engines	100	0	0
Stars in Histoire Céleste	331	18	6
Stars in Lacaille	11	0	0
Stars in R.A.S. Catalogue	6	16	6
Animal Secretions	10	10	0
Steam-engines in Cornwall	50	0	0
Atmospheric Air	16	1	0
Cast and Wrought Iron	40	0	0
Heat on Organic Bodies	3	0	0
Gases on Solar Spectrum	22	0	0
Hourly Meteorological Observations, Inverness and Kingussie	49	7	8
Fossil Reptiles	118	2	9
Mining Statistics	50	0	0
	£1595	11	0
1840.			
Bristol Tides	100	0	0
Subterranean Temperature	13	13	6
Heart Experiments	18	19	0
Lungs Experiments	8	13	0
Tide Discussions	50	0	0
Land and Sea Level	6	11	1
Stars (Histoire Céleste)	242	10	0
Stars (Lacaille)	4	15	0
Stars (Catalogue)	264	0	0
Atmospheric Air	15	15	0
Water on Iron	10	0	0
Heat on Organic Bodies	7	0	0
Meteorological Observations	52	17	6
Foreign Scientific Memoirs	112	1	6
Working Population	100	0	0
School Statistics	50	0	0
Forms of Vessels	184	7	0
Chemical and Electrical Phenomena	40	0	0
Meteorological Observations at Plymouth	80	0	0
Magnetical Observations	185	13	9
	£1546	16	4
1841.			
Observations on Waves	30	0	0
Meteorology and Subterranean Temperature	8	8	0
Actinometers	10	0	0
Earthquake Shocks	17	7	0
Acrid Poisons	6	0	0
Veins and Absorbents	3	0	0
Mud in Rivers	5	0	0
Marine Zoology	15	12	8
Skeleton Maps	20	0	0
Mountain Barometers	6	18	6
Stars (Histoire Céleste)	185	0	0

	£	s.	d.
Stars (Lacaille)	79	5	0
Stars (Nomenclature of)	17	19	6
Stars (Catalogue of)	40	0	0
Water on Iron	50	0	0
Meteorological Observations at Inverness	20	0	0
Meteorological Observations (reduction of)	25	0	0
Fossil Reptiles	50	0	0
Foreign Memoirs	62	0	0
Railway Sections	38	1	6
Forms of Vessels	193	12	0
Meteorological Observations at Plymouth	55	0	0
Magnetical Observations	61	18	8
Fishes of the Old Red Sandstone	100	0	0
Tides at Leith	50	0	0
Anemometer at Edinburgh	69	1	10
Tabulating Observations	9	6	3
Races of Men	5	0	0
Radiate Animals	2	0	0
	£1235	10	11

1842.

	£	s.	d.
Dynamometric Instruments	113	11	2
Anoplura Britanniæ	52	12	0
Tides at Bristol	59	8	0
Gases on Light	30	14	7
Chronometers	26	17	6
Marine Zoology	1	5	0
British Fossil Mammalia	100	0	0
Statistics of Education	20	0	0
Marine Steam-vessels' Engines	28	0	0
Stars (Histoire Céleste)	59	0	0
Stars (Brit. Assoc. Cat. of)	110	0	0
Railway Sections	161	10	0
British Belemnites	50	0	0
Fossil Reptiles (publication of Report)	210	0	0
Forms of Vessels	180	0	0
Galvanic Experiments on Rocks	5	8	6
Meteorological Experiments at Plymouth	68	0	0
Constant Indicator and Dynamometric Instruments	90	0	0
Force of Wind	10	0	0
Vight on Growth of Seeds	8	0	0
Lital Statistics	50	0	0
Vegetative Power of Seeds	8	1	11
Questions on Human Race	7	9	0
	£1449	17	8

1843.

	£	s.	d.
Revision of the Nomenclature of Stars	2	0	0
Reduction of Stars, British Association Catalogue	25	0	0
Anomalous Tides, Frith of Forth	120	0	0
Hourly Meteorological Observations at Kingussie and Inverness	77	12	8
Meteorological Observations at Plymouth	55	0	0
Whewell's Meteorological Anemometer at Plymouth	10	0	0
Meteorological Observations, Osler's Anemometer at Plymouth	20	0	0
Reduction of Meteorological Observations	30	0	0
Meteorological Instruments and Gratuities	39	6	0
Construction of Anemometer at Inverness	56	12	2
Magnetic Coöperation	10	8	10
Meteorological Recorder for Kew Observatory	50	0	0
Action of Gases on Light	18	16	1
Establishment at Kew Observatory, Wages, Repairs, Furniture and Sundries	133	4	7
Experiments by Captive Balloons	81	8	0
Oxidation of the Rails of Railways	20	0	0
Publication of Report on Fossil Reptiles	40	0	0
Coloured Drawings of Railway Sections	147	18	3
Registration of Earthquake Shocks	30	0	0
Report on Zoological Nomenclature	10	0	0
Uncovering Lower Red Sandstone near Manchester	4	4	6
Vegetative Power of Seeds	5	3	8
Marine Testacea (Habits of)	10	0	0
Marine Zoology	10	0	0
Marine Zoology	2	14	11
Preparation of Report on British Fossil Mammalia	100	0	0
Physiological Operations of Medicinal Agents	20	0	0
Vital Statistics	36	5	8
Additional Experiments on the Forms of Vessels	70	0	0
Additional Experiments on the Forms of Vessels	100	0	0
Reduction of Experiments on the Forms of Vessels	100	0	0
Morin's Instrument and Constant Indicator	69	14	10
Experiments on the Strength of Materials	60	0	0
	£1565	10	2

1844.

	£	s.	d.
Meteorological Observations at Kingussie and Inverness	12	0	0
Completing Observations at Plymouth	35	0	0
Magnetic and Meteorological Coöperation	25	8	4
Publication of the British Association Catalogue of Stars	35	0	0
Observations on Tides on the East coast of Scotland	100	0	0
Revision of the Nomenclature of Stars 1842	2	9	6
Maintaining the Establishment in Kew Observatory	117	17	3
Instruments for Kew Observatory	56	7	3

	£	s.	d.
Influence of Light on Plants......	10	0	0
Subterraneous Temperature in Ireland	5	0	0
Coloured Drawings of Railway Sections	15	17	6
Investigation of Fossil Fishes of the Lower Tertiary Strata ...	100	0	0
Registering the Shocks of Earthquakes 1842	23	11	10
Structure of Fossil Shells	20	0	0
Radiata and Mollusca of the Ægean and Red Seas......1842	100	0	0
Geographical Distributions of Marine Zoology 1842	10	0	0
Marine Zoology of Devon and Cornwall	10	0	0
Marine Zoology of Corfu	10	0	0
Experiments on the Vitality of Seeds	9	0	3
Experiments on the Vitality of Seeds 1842	8	7	3
Exotic Anoplura	15	0	0
Strength of Materials	100	0	0
Completing Experiments on the Forms of Ships	100	0	0
Inquiries into Asphyxia	10	0	0
Investigations on the Internal Constitution of Metals	50	0	0
Constant Indicator and Morin's Instrument 1842	10	3	6
	£981	12	8

1845.

	£	s.	d.
Publication of the British Association Catalogue of Stars	351	14	6
Meteorological Observations at Inverness	30	18	11
Magnetic and Meteorological Cooperation	16	16	8
Meteorological Instruments at Edinburgh	18	11	9
Reduction of Anemometrical Observations at Plymouth	25	0	0
Electrical Experiments at Kew Observatory	43	17	8
Maintaining the Establishment in Kew Observatory	149	15	0
For Kreil's Barometrograph......	25	0	0
Gases from Iron Furnaces	50	0	0
The Actinograph	15	0	0
Microscopic Strueture of Shells	20	0	0
Exotic Anoplura 1843	10	0	0
Vitality of Seeds 1843	2	0	7
Vitality of Seeds 1844	7	0	0
Marine Zoology of Cornwall ...	10	0	0
Physiological Action of Medicines	20	0	0
Statistics of Sickness and Mortality in York	20	0	0
Earthquake Shocks 1843	15	14	8
	£830	9	9

1846.

	£	s.	d.
British Association Catalogue of Stars 1844	211	15	0
Fossil Fishes of the London Ciey	100	0	0
Computation of the Gaussian Constants for 1829	50	0	0
Maintaining the Establishment at Kew Observatory	146	16	7
Strength of Materials	60	0	0
Researches in Asphyxia	6	16	2
Examination of Fossil Shells......	10	0	0
Vitality of Seeds 1844	2	15	10
Vitality of Seeds 1845	7	12	3
Marine Zoology of Cornwall......	10	0	0
Marine Zoology of Britaiu	10	0	0
Exotic Anoplura 1844	25	0	0
Expenses attending Anemometers	11	7	6
Anemometers' Repairs	2	3	6
Atmospheric Waves	3	3	3
Captive Balloons 1844	8	19	3
Varieties of the Human Race 1844	7	6	3
Statistics of Sickness and Mortality in York	12	0	0
	£685	16	0

1847.

	£	s.	d.
Computation of the Gaussian Constants for 1829	50	0	0
Habits of Marine Animals	10	0	0
Physiological Action of Medicsnes	20	0	0
Marine Zoology of Cornwall......	10	0	0
Atmospheric Waves	6	9	3
Vitality of Seeds	4	7	7
Maintaining the Establishment at Kew Observatory	107	8	6
	£208	5	4

1848.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	171	15	11
Atmospheric Waves	3	10	9
Vitality of Seeds	9	15	0
Completion of Catalogues of Stars	70	0	0
On Colouring Matters	5	0	0
On Growth of Plants...............	15	0	0
	£275	1	8

1849.

	£	s.	d.
Electrical Observations at Kew Observatory	50	0	0
Maintaining Establishment at ditto	76	2	5
Vitality of Seeds	5	8	1
On Growth of Plants...............	5	0	0
Regiatration of Periodical Phenomena	10	0	0
Bill on account of Anemometrical Observations	13	9	0
	£159	19	6

1850.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	255	18	0
Transit of Earthquake Waves ...	50	0	0
Periodical Phenomena	15	0	0
Meteorological Instrument, Azores	25	0	0
	£345	18	0

	£	s.	d.
1851.			
Maintaining the Establishment at Kew Observatory (includes part of grant in 1849)	309	2	2
Theory of Heat	20	1	1
Periodical Phenomena of Animals and Plants	5	0	0
Vitality of Seeds	5	6	4
Influence of Solar Radiation	30	0	0
Ethnological Inquiries	12	0	0
Researches on Annelida	10	0	0
	£391	9	7
1852.			
Maintaining the Establishment at Kew Observatory (including balance of grant for 1850)	233	17	8
Experiments on the Conduction of Heat	5	2	9
Influence of Solar Radiations	20	0	0
Geological Map of Ireland	15	0	0
Researches on the British Annelida	10	0	0
Vitality of Seeds	10	6	2
Strength of Boiler Plates	10	0	0
	£304	6	7
1853.			
Maintaining the Establishment at Kew Observatory	165	0	0
Experiments on the Influence of Solar Radiation	15	0	0
Researches on the British Annelida	10	0	0
Dredging on the East Coast of Scotland	10	0	0
Ethnological Queries	5	0	0
	£205	0	0
1854.			
Maintaining the Establishment at Kew Observatory (including balance of former grant)	330	15	4
Investigations on Flax	11	0	0
Effects of Temperature on Wrought Iron	10	0	0
Registration of Periodical Phenomena	10	0	0
British Annelida	10	0	0
Vitality of Seeds	5	2	3
Conduction of Heat	4	2	0
	£380	19	7
1855.			
Maintaining the Establishment at Kew Observatory	425	0	0
Earthquake Movements	10	0	0
Physical Aspect of the Moon	11	8	5
Vitality of Seeds	10	7	11
Map of the World	15	0	0
Ethnological Queries	5	0	0
Dredging near Belfast	4	0	0
	£480	16	4
1856.			
Maintaining the Establishment at Kew Observatory:— 1854......£ 75 0 0; 1855......£500 0 0	575	0	0
Strickland's Ornithological Synonyms	100	0	0
Dredging and Dredging Forms	9	13	9
Chemical Action of Light	20	0	0
Strength of Iron Plates	10	0	0
Registration of Periodical Phenomena	10	0	0
Propagation of Salmon	10	0	0
	£734	13	9
1857.			
Maintaining the Establishment at Kew Observatory	350	0	0
Earthquake Wave Experiments	40	0	0
Dredging near Belfast	10	0	0
Dredging on the West Coast of Scotland	10	0	0
Investigations into the Mollusca of California	10	0	0
Experiments on Flax	5	0	0
Natural History of Madagascar	20	0	0
Researches on British Annelida	25	0	0
Report on Natural Products imported into Liverpool	10	0	0
Artificial Propagation of Salmon	10	0	0
Temperature of Mines	7	8	0
Thermometers for Subterranean Observations	5	7	4
Life-Boats	5	0	0
	£507	15	4
1858.			
Maintaining the Establishment at Kew Observatory	500	0	0
Earthquake Wave Experiments	25	0	0
Dredging on the West Coast of Scotland	10	0	0
Dredging near Dublin	5	0	0
Vitality of Seeds	5	5	0
Dredging near Belfast	18	13	2
Report on the British Annelida	25	0	0
Experiments on the production of Heat by Motion in Fluids	20	0	0
Report on the Natural Products imported into Scotland	10	0	0
	£618	18	2
1859.			
Maintaining the Establishment at Kew Observatory	500	0	0
Dredging near Dublin	15	0	0
Osteology of Birds	50	0	0
Irish Tunicata	5	0	0
Manure Experiments	20	0	0
British Medusidæ	5	0	0
Dredging Committee	5	0	0
Steam-vessels' Performance	5	0	0
Marine Fauna of South and West of Ireland	10	0	0
Photographic Chemistry	10	0	0
Lanarkshire Fossils	20	0	1
Balloon Ascents	39	11	0
	£684	11	1
1860.			
Maintaining the Establishment of Kew Observatory	500	0	0
Dredging near Belfast	16	6	0
Dredging in Dublin Bay	15	0	0

	£	s.	d.
Inquiry into the Performance of Steam-vessels	124	0	0
Explorations in the Yellow Sandstone of Dura Den	20	0	0
Chemico-mechanical Analysis of Rocks and Minerals	25	0	0
Researches on the Growth of Plants	10	0	0
Researches on the Solubility of Salts	30	0	0
Researches on the Constituents of Manures	25	0	0
Balance of Captive Balloon Accounts	1	13	6
	£1241	7	0

1861.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	500	0	0
Earthquake Experiments	25	0	0
Dredging North and East Coasts of Scotland	23	0	0
Dredging Committee :— 1860 ...... £50 0 0; 1861 ...... £22 0 0	72	0	0
Excavations at Dura Den	20	0	0
Solubility of Salts	20	0	0
Steam-vessel Performance	150	0	0
Fossils of Lesmahago	15	0	0
Explorations at Uriconium	20	0	0
Chemical Alloys	20	0	0
Classified Index to the Transactions	100	0	0
Dredging in the Mersey and Dee	5	0	0
Dip Circle	30	0	0
Photoheliographic Observations	50	0	0
Prison Diet	20	0	0
Gauging of Water	10	0	0
Alpine Ascents	6	5	1
Constituents of Manures	25	0	0
	£1111	5	10

1862.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	500	0	0
Patent Laws	21	6	0
Mollusca of N.-W. America	10	0	0
Natural History by Mercantile Marine	5	0	0
Tidal Observations	25	0	0
Photoheliometer at Kew	40	0	0
Photographic Pictures of the Sun	150	0	0
Rocks of Donegal	25	0	0
Dredging Durham and Northumberland	25	0	0
Connexion of Storms	20	0	0
Dredging North-east Coast of Scotland	6	9	6
Ravages of Teredo	3	11	0
Standards of Electrical Resistance	50	0	0
Railway Accidents	10	0	0
Balloon Committee	200	0	0
Dredging Dublin Bay	10	0	0
Dredging the Mersey	5	0	0
Prison Diet	20	0	0
Gauging of Water	12	10	0
Steamships' Performance	150	0	0
Thermo-Electric Currents	5	0	0
	£1293	16	6

1863.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Balloon Committee deficiency	70	0	0
Balloon Ascents (other expenses)	25	0	0
Entozoa	25	0	0
Coal Fossils	20	0	0
Herrings	20	0	0
Granites of Donegal	5	0	0
Prison Diet	20	0	0
Vertical Atmospheric Movements	13	0	0
Dredging Shetland	50	0	0
Dredging North-east coast of Scotland	25	0	0
Dredging Northumberland and Durham	17	3	10
Dredging Committee superintendence	10	0	0
Steamship Performance	100	0	0
Balloon Committee	200	0	0
Carbon under pressure	10	0	0
Volcanic Temperature	100	0	0
Bromide of Ammonium	8	0	0
Electrical Standards	100	0	0
—— Construction and distribution	40	0	0
Luminous Meteors	17	0	0
Kew Additional Buildings for Photoheliograph	100	0	0
Thermo-Electricity	15	0	0
Analysis of Rocks	8	0	0
Hydroida	10	0	0
	£1608	3	10

1864.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Coal Fossils	20	0	0
Vertical Atmospheric Movements	20	0	0
Dredging Shetland	75	0	0
Dredging Northumberland	25	0	0
Balloon Committee	200	0	0
Carbon under pressure	10	0	0
Standards of Electric Resistance	100	0	0
Analysis of Rocks	10	0	0
Hydroida	10	0	0
Askham's Gift	50	0	0
Nitrite of Amyle	10	0	0
Nomenclature Committee	5	0	0
Rain-Gauges	19	15	8
Cast-Iron Investigation	20	0	0
Tidal Observations in the Humber	50	0	0
Spectral Rays	45	0	0
Luminous Meteors	20	0	0
	£1289	15	8

1865.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Balloon Committee	100	0	0
Hydroida	13	0	0

	£	s.	d.
Rain-Gauges	30	0	0
Tidal Observations in the Humber	6	8	0
Hexylic Compounds	20	0	0
Amyl Compounds	20	0	0
Irish Flora	25	0	0
American Mollusca	3	9	0
Organic Acids	20	0	0
Lingula Flags Excavation	10	0	0
Eurypterus	50	0	0
Electrical Standards	100	0	0
Malta Caves Researches	30	0	0
Oyster Breeding	25	0	0
Gibraltar Caves Researches	150	0	0
Kent's Hole Excavations	100	0	0
Moon's Surface Observations	35	0	0
Marine Fauna	25	0	0
Dredging Aberdeenshire	25	0	0
Dredging Channel Islands	50	0	0
Zoological Nomenclature	5	0	0
Resistance of Floating Bodies in Water	100	0	0
Bath Waters Analysis	8	10	0
Luminous Meteors	40	0	0
	£1591	7	10
1866.			
Maintaining the Establishment of Kew Observatory	600	0	0
Lunar Committee	64	13	4
Balloon Committee	50	0	0
Metrical Committee	50	0	0
British Rainfall	50	0	0
Kilkenny Coal Fields	16	0	0
Alum Bay Fossil Leaf-Bed	15	0	0
Luminous Meteors	50	0	0
Lingula Flags Excavation	20	0	0
Chemical Constitution of Cast Iron	50	0	0
Amyl Compounds	25	0	0
Electrical Standards	100	0	0
Malta Caves Exploration	30	0	0
Kent's Hole Exploration	200	0	0
Marine Fauna, &c., Devon and Cornwall	25	0	0
Dredging Aberdeenshire Coast	25	0	0
Dredging Hebrides Coast	50	0	0
Dredging the Mersey	5	0	0
Resistance of Floating Bodies in Water	50	0	0
Polycyanides of Organic Radicals	20	0	0
Rigor Mortis	10	0	0
Irish Annelida	15	0	0
Catalogue of Crania	50	0	0
Didine Birds of Mascarene Islands	50	0	0
Typical Crania Researches	30	0	0
Palestine Exploration Fund	100	0	0
	£1750	13	4
1867.			
Maintaining the Establishment of Kew Observatory	600	0	0
Meteorological Instruments, Palestine	50	0	0
Lunar Committee	120	0	0

	£	s.	d.
Metrical Committee	30	0	0
Kent's Hole Explorations	100	0	0
Palestine Explorations	50	0	0
Insect Fauna, Palestine	30	0	0
British Rainfall	50	0	0
Kilkenny Coal Fields	25	0	0
Alum Bay Fossil Leaf-Bed	25	0	0
Luminous Meteors	50	0	0
Bournemouth, &c. Leaf-Beds	30	0	0
Dredging Shetland	75	0	0
Steamship Reports Condensation	100	0	0
Electrical Standards	100	0	0
Ethyle and Methyle series	25	0	0
Fossil Crustacea	25	0	0
Sound under Water	24	4	0
North Greenland Fauna	75	0	0
Do. Plant Beds	100	0	0
Iron and Steel Manufacture	25	0	0
Patent Laws	30	0	0
	£1739	4	0
1868.			
Maintaining the Establishment of Kew Observatory	600	0	0
Lunar Committee	120	0	0
Metrical Committee	50	0	0
Zoological Record	100	0	0
Kent's Hole Explorations	150	0	0
Steamship Performances	100	0	0
British Rainfall	50	0	0
Luminous Meteors	50	0	0
Organic Acids	60	0	0
Fossil Crustacea	25	0	0
Methyl series	25	0	0
Mercury and Bile	25	0	0
Organic remains in Limestone Rocks	25	0	0
Scottish Earthquakes	20	0	0
Fauna, Devon and Cornwall	30	0	0
British Fossil Corals	50	0	0
Bagshot Leaf-beds	50	0	0
Greenland Explorations	100	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature	50	0	0
Spectroscopic investigations of Animal Substances	5	0	0
Secondary Reptiles, &c.	30	0	0
British Marine Invertebrate Fauna	100	0	0
	£1940	0	0
1869.			
Maintaining the Establishment of Kew Observatory	600	0	0
Lunar Committee	50	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Committee on Gases in Deep-well Water	25	0	0
British Rainfall	50	0	0
Thermal Conductivity of Iron, &c.	30	0	0
Kent's Hole Explorations	150	0	0
Steamship Performances	30	0	0

	£	s.	d.
Chemical Constitution of Cast Iron	80	0	0
Iron and Steel Manufacture	100	0	0
Methyl Series	30	0	0
Organic remains in Limestone Rocks	10	0	0
Earthquakes in Scotland	10	0	0
British Fossil Corals	50	0	0
Bagshot Leaf-Beds	30	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature	30	0	0
Spectroscopic Investigations of Animal Substances	5	0	0
Organic Acids	12	0	0
Kiltorcan Fossils	20	0	0
Chemical Constitution and Physiological Action Relations	15	0	0
Mountain Limestone Fossils	25	0	0
Utilization of Sewage	10	0	0
Products of Digestion	10	0	0
	£1622	0	0

1870.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Committee on Marine Fauna	20	0	0
Ears in Fishes	10	0	0
Chemical nature of Cast Iron	80	0	0
Luminous Meteors	30	0	0
Heat in the Blood	15	0	0
British Rainfall	100	0	0
Thermal Conductivity of Iron &c.	20	0	0
British Fossil Corals	50	0	0
Kent's Hole Explorations	150	0	0
Scottish Earthquakes	4	0	0
Bagshot Leaf-Beds	15	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature	50	0	0
Kiltorcan Quarries Fossils	20	0	0
Mountain Limestone Fossils	25	0	0
Utilization of Sewage	50	0	0
Organic Chemical Compounds	30	0	0
Onny River Sediment	3	0	0
Mechanical Equivalent of Heat	50	0	0
	£1572	0	0

1871.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Monthly Reports of Progress in Chemistry	100	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Thermal Equivalents of the Oxides of Chlorine	10	0	0
Tidal Observations	100	0	0
Fossil Flora	25	0	0
Luminous Meteors	30	0	0
British Fossil Corals	25	0	0
Heat in the Blood	7	2	6
British Rainfall	50	0	0
Kent's Hole Explorations	150	0	0
Fossil Crustacea	25	0	0
Methyl Compounds	25	0	0
Lunar Objects	20	0	0
Fossil Corals Sections, for Photographing	20	0	0
Bagshot Leaf-Beds	20	0	0
Moab Explorations	100	0	0
Gaussian Constants	40	0	0
	£1472	2	6

1872.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	300	0	0
Metrical Committee	75	0	0
Zoological Record	100	0	0
Tidal Committee	200	0	0
Carboniferous Corals	25	0	0
Organic Chemical Compounds	25	0	0
Exploration of Moab	100	0	0
Terato-Embryological Inquiries	10	0	0
Kent's Cavern Exploration	100	0	0
Luminous Meteors	20	0	0
Heat in the Blood	15	0	0
Fossil Crustacea	25	0	0
Fossil Elephants of Malta	25	0	0
Lunar Objects	20	0	0
Inverse Wave-Lengths	20	0	0
British Rainfall	100	0	0
Poisonous Substances Antagonism	10	0	0
Essential Oils, Chemical Constitution, &c.	40	0	0
Mathematical Tables	50	0	0
Thermal Conductivity of Metals	25	0	0
	£1285	0	0

General Meetings.

On Wednesday Evening, August 14, at 8 P.M., in the Dome, Professor Sir William Thomson, LL.D., F.R.S., President, resigned the office of President to Dr. W. B. Carpenter, LL.D., F.R.S., who took the Chair, and delivered an Address, for which see page lxix.

On Thursday Evening, August 15, at 8 P.M., a Soirée took place in the Dome, Corn Exchange, and Museum.

On Friday Evening, August 16, at 8.30 P.M., in the Dome, Professor P. Martin Duncan, M.D., F.R.S., delivered a Discourse on "Insect Metamorphosis."

On Saturday Evening, at 8 P.M., in the Dome, William Spottiswoode, LL.D., F.R.S., delivered a Discourse entitled "Sunshine, Sea, and Sky," to the Operative Classes of Brighton.

On Monday Evening, August 19, at 8.30 P.M., in the Dome, Prof. W. K. Clifford delivered a Discourse on "The Aims and Instruments of Scientific Thought."

On Tuesday Evening, August 20, at 8 P.M., a Soirée took place in the Dome, Corn Exchange, and Museum.

On Wednesday, August 21, at 2.30 P.M., the concluding General Meeting took place, when the Proceedings of the General Committee, and the Grants of Money for Scientific purposes, were explained to the Members.

The Meeting was then adjourned to Bradford*.

* The Meeting is appointed to take place on Wednesday, September 17, 1873.

ADDRESS

OF

WILLIAM B. CARPENTER, M.D., LL.D., F.R.S.,

PRESIDENT.

My Lords, Ladies, and Gentlemen,

Thirty-six years have now elapsed since at the first and (I regret to say) the only Meeting of this Association held in Bristol,—which Ancient City followed immediately upon our National Universities in giving it a welcome, —I enjoyed the privilege which I hold it one of the most valuable functions of these Annual assemblages to bestow; that of coming into personal relation with those distinguished Men whose names are to every cultivator of Science as "household words," and the light of whose brilliant example, and the warmth of whose cordial encouragement are the most precious influences by which his own aspirations can be fostered and directed. Under the Presidency of the Marquis of Lansdowne, with Conybeare and Prichard as Vice-Presidents, with Vernon Harcourt as General Secretary, and John Phillips as Assistant Secretary, were gathered together Whewell and Peacock, James Forbes and Sir W. Rowan Hamilton, Murchison and Sedgwick, Buckland and De la Beche, Henslow and Daubeny, Roget, Richardson, and Edward Forbes, with many others, perhaps not less distinguished, of whom my own recollection is less vivid.

In his honoured old age, Sedgwick still retains, in the Academic home of his life, all his pristine interest in whatever bears on the advance of the Science he has adorned as well as enriched; and Phillips still cultivates with all his old enthusiasm the congenial soil to which he has been transplanted. But the rest,—our fathers and elder brothers,—"Where are they?" It is for us of the present generation to show that they live in our lives; to carry forward the work which they commenced; and to transmit the influence of their example to our own successors.

There is one of these great men, whose departure from among us since last we met claims a special notice, and whose life—full as it was of years and honours—we should have all desired to see prolonged for a few months, could its feebleness have been unattended with suffering. For we should all then have sympathized with Murchison, in the delight with which he would have received the intelligence of the safety of the friend in whose scientific labours and personal welfare he felt to the last the keenest interest. That this intelligence, which our own Expedition for the relief of Livingstone would have

obtained (we will hope) a few months later, should have been brought to us through the generosity of one, and the enterprising ability—may I not use our peculiarly English word, the "pluck"—of another of our American brethren, cannot but be a matter of national regret to us. But let us bury that regret in the common joy which both Nations feel in the result; and while we give a cordial welcome to Mr. Stanley, let us glory in the prospect now opening, that England and America will co-operate in that noble object which—far more than the discovery of the Sources of the Nile—our great Traveller has set before himself as his true mission, the Extinction of the Slave Trade.

At the last Meeting of this Association, I had the pleasure of being able to announce, that I had received from the First Lord of the Admiralty a favourable reply to a representation I had ventured to make to him, as to the importance of prosecuting on a more extended scale the course of inquiry into the Physical and Biological conditions of the Deep Sea, on which, with my colleagues Prof. Wyville Thomson and Mr. J. Gwyn Jeffreys, I had been engaged for the three preceding years. That for which I had asked was a Circumnavigating Expedition of at least three years' duration, provided with an adequate Scientific Staff, and with the most complete Equipment that our experience could devise. The Council of the Royal Society having been led by the encouraging tenor of the answer I had received, to make a formal Application to this effect, the liberal arrangements of the Government have been carried out under the advice of a Scientific Committee which included Representatives of this Association. H. M. ship 'Challenger,' a vessel in every way suitable for the purpose, is now being fitted out at Sheerness; the Command of the Expedition is intrusted to Captain Nares, an Officer of whose high qualifications I have myself the fullest assurance; while the Scientific charge of it will be taken by my excellent friend Prof. Wyville Thomson, at whose suggestion it was that these investigations were originally commenced, and whose zeal for the efficient prosecution of them is shown by his relinquishment for a time of the important Academic position he at present fills. It is anticipated that the Expedition will sail in November next; and I feel sure that the good wishes of all of you will go along with it.

The confident anticipation expressed by my predecessor, that for the utilization of the total Eclipse of the Sun then impending, our Government would "exercise the same wise liberality as heretofore in the interests of Science," has been amply fulfilled. An Eclipse-Expedition to India was organized at the charge of the Home Government, and placed under the direction of Mr. Lockyer; the Indian Government contributed its quota to the work; and a most valuable body of results was obtained, of which, with those of the previous year, a Report is now being prepared under the direction of the Council of the Astronomical Society.

It has been customary with successive occupants of this Chair, distinguished as Leaders in their several divisions of the noble Army of Science, to open the proceedings of the Meetings over which they respectively presided, with a Discourse on some aspect of Nature in her Relation to Man. But I am not aware that any one of them has taken up the other side of the inquiry,—that which concerns Man as the "Interpreter of Nature;" and I have therefore thought it not inappropriate to lead you to the consideration of the Mental processes, by which are formed those fundamental conceptions of Matter and Force, of Cause and Effect, of Law and Order, which furnish the basis of all scientific reasoning, and constitute the *Phi-*

losophia prima of Bacon. There is a great deal of what I cannot but regard as fallacious and misleading Philosophy—"oppositions of Science falsely so called"—abroad in the world at the present time. And I hope to satisfy you, that those who set up *their own conceptions* of the Orderly Sequence which they discern in the Phenomena of Nature, as fixed and determinate *Laws*, by which those phenomena not only *are* within all Human experience, but always *have been*, and always *must be*, invariably governed, are really guilty of the Intellectual arrogance they condemn in the Systems of the Ancients, and place themselves in diametrical antagonism to those real Philosophers, by whose comprehensive grasp and penetrating insight that Order has been so far disclosed. For what love of the Truth as it is in Nature was ever more conspicuous, than that which Kepler displayed, in his abandonment of each of the ingenious conceptions of the Planetary System which his fertile Imagination had successively devised, so soon as it proved to be inconsistent with the facts disclosed by observation? In that almost admiring description of the way in which his enemy Mars, "whom he had left at home a despised Captive," had "burst all the chains of the equations, and broke forth from the prisons of the tables," who does not recognize the justice of Schiller's definition of the real Philosopher, as one who always loves Truth better than his System? And when at last he had gained the full assurance of a success so complete that (as he says) he thought he must be dreaming, or that he had been reasoning in a circle, who does not feel the almost sublimity of the self-abnegation, with which, after attaining what was in his own estimation such a glorious reward of his life of toil, disappointment, and self-sacrifice, he abstains from claiming the applause of his contemporaries, but leaves his fame to after ages in these noble words: "The book is written; to be read either now or by posterity, I care not "which. It may well wait a century for a reader, as God has waited six "thousand years for an observer."

And when a yet greater than Kepler was bringing to its final issue that grandest of all Scientific Conceptions, long pondered over by his almost superhuman intellect,—which linked together the Heavens and the Earth, the Planets and the Sun, the Primaries and their Satellites, and included even the vagrant Comets, in the *nexus* of a Universal Attraction—establishing for all time the truth for whose utterance Galileo had been condemned, and giving to Kepler's Laws a significance of which their author had never dreamed,—what was the meaning of that agitation which prevented the Philosopher from completing his computation, and compelled him to hand it over to his friend? That it was not the thought of his own greatness, but the glimpse of the grand Universal Order thus revealed to his mental vision, which shook the serene and massive soul of Newton to its foundations, we have the proof in that beautiful comparison in which he likened himself to a Child picking up shells on the shore of the vast Ocean of Truth; —a comparison which will be evidence to all time at once of his true Philosophy and of his profound Humility.

Though it is with the Intellectual Representation of Nature which we call *Science*, that we are primarily concerned, it will not be without its use to cast a glance in the first instance at the other two principal characters under which Man acts as her Interpreter,—those, namely, of the Artist and of the Poet.

The Artist serves as the Interpreter of Nature, not when he works as the mere copyist, delineating that which he sees with his bodily eyes, and which we could see as well for ourselves; but when he endeavours to awaken within

us the perception of those beauties and harmonies which his own trained sense has recognized, and thus impart to us the pleasure he has himself derived from their contemplation. As no two Artists agree in the original constitution and acquired habits of their Minds, all look at Nature with different (mental) eyes; so that to each, *Nature is what he individually sees in her.*

The Poet, again, serves as the Interpreter of Nature, not so much when by skilful word-painting (whether in prose or verse) he calls up before our mental vision the picture of some actual or ideal scene, however beautiful; as when, by rendering into appropriate forms those deeper impressions made by the Nature around him on the Moral and Emotional part of his own Nature, he transfers these impressions to the corresponding part of ours. For it is the attribute of the true Poet to penetrate the secret of those mysterious influences which we all unknowingly experience; and having discovered this to himself, to bring others, by the power he thus wields, into the like sympathetic relation with Nature,—evoking with skilful touch the varied response of the Soul's finest chords, heightening its joys, assuaging its griefs, and elevating its aspirations. Whilst, then, the Artist aims to picture what he *sees* in Nature, it is the object of the Poet to represent what he *feels* in Nature; and to each true Poet, *Nature is what he individually finds in her.*

The Philosopher's interpretation of Nature *seems* less individual than that of the Artist or the Poet, because it is based on facts which any one may verify, and is elaborated by reasoning processes of which all admit the validity. He looks at the Universe as a vast Book lying open before him, of which he has in the first place to learn the characters, then to master the language, and finally to apprehend the ideas which that language conveys. In that Book there are many Chapters, treating of different subjects; and as Life is too short for any one man to grasp the whole, the Scientific interpretation of this Book comes to be the work of many Intellects, differing not merely in the range but also in the character of their powers. But whilst there are "diversities of gifts," there is "the same spirit." While each takes his special direction, the general Method of study is the same for all. And it is a testimony alike to the truth of that Method and to the Unity of Nature, that there is an ever-increasing tendency towards agreement among those who use it aright;—temporary differences of interpretation being removed, sometimes by a more complete mastery of her language, sometimes by a better apprehension of her ideas;—and lines of pursuit which had seemed entirely distinct or even widely divergent, being found to lead at last to one common goal. And it is this agreement which gives rise to the general belief—in many, to the confident assurance—that the Scientific interpretation of Nature represents her not merely as she *seems*, but as she *really is.*

But when we carefully examine the foundation of that assurance, we find reason to distrust its security; for it can be shown to be no less true of the Scientific conception of Nature, than it is of the Artistic or the Poetic, that it is *a representation framed by the Mind itself* out of the materials supplied by the impressions which external objects make upon the Senses; so that to each Man of Science, *Nature is what he individually believes her to be.* And that belief will rest on very different bases, and will have very unequal values, in different departments of Science.—Thus in what are commonly known as the "exact" Sciences, of which Astronomy may be taken as the type, the data afforded by precise methods of observation can be made the basis of reasoning, in every step of which the Mathematician feels the fullest assurance of certainty; and the final deduction is justified either by

its conformity to known or ascertainable facts,—as when Kepler determined the elliptic orbit of Mars; or by the fulfilment of the predictions it has sanctioned,—as in the occurrence of an Eclipse or an Occultation at the precise moment specified many years previously; or, still more emphatically, by the actual discovery of phenomena till then unrecognized,—as when the Perturbations of the planets, shown by Newton to be the necessary results of their mutual attraction, were proved by observation to have a real existence; or as when the unknown disturber of Uranus was found in the place assigned to him by the computations of Adams and Le Verrier.

We are accustomed, and I think most rightly, to speak of these achievements as triumphs of the Human Intellect. But the very phrase implies that the work is done by Mental Agency. And even in the very first stage of the process—*the interpretation of observations*—there is often a liability to serious error. Of this we have a most noteworthy example in the fact that the estimated distance of the Earth from the Sun, deduced from observations of the last Transit of Venus, is now pretty certainly known to be about three millions of miles too great; the strong indications of such an excess afforded by the nearly coincident results of other modes of inquiry having led to a reexamination of the record, which was found, when fairly interpreted, fully to *justify*—if not even to require—the reduction. Even the verification of the prediction is far from proving the Intellectual process by which it was made to have been correct. For we learn from the honest confessions of Kepler, that he was led to the discovery of the Elliptic orbit of Mars by a series of happy accidents, which turned his erroneous guesses into the right direction; and to that of the passage of the Radius Vector over *equal areas in equal times*, by the notion of a whirling force emanating from the Sun, which we now regard as an entirely wrong conception of the cause of orbital revolution *. It should always be remembered, moreover, that the Ptolemaic system of Astronomy, with all its cumbrous ideal mechanism of "Centric and Excentric, Cycle and Epicycle, Orb in Orb," did intellectually represent all that the Astronomer, prior to the invention of the Telescope, could see from his actual standpoint, the Earth, with an accuracy which was proved by the fulfilment of his predictions. And in that last and most memorable anticipation which has given an imperishable fame to our two illustrious contemporaries, the inadequacy of the basis afforded by actual observation of the perturbations of Uranus, required that it should be supplemented by an assumption of the probable distance of the disturbing Planet beyond, which has been shown by subsequent observation to have been only an approximation to the truth.

Even in this most exact of Sciences, therefore, we cannot proceed a step, without translating the actual Phenomena of Nature into Intellectual Representations of those phenomena; and it is because the Newtonian conception is not only the most simple, but is also, up to the extent of our present knowledge, *universal* in its conformity to the facts of observation, that we accept it as the only Scheme of the Universe yet promulgated, which satisfies our Intellectual requirements.

When, under the reign of the Ptolemaic System, any new inequality was discovered in the motion of a Planet, a new wheel had to be added to the ideal Mechanism,—as Ptolemy said, "to save appearances." If it should prove, a century hence, that the motion of Neptune himself is disturbed by some other attraction than that exerted by the interior Planets, we should confidently expect that not an *ideal* but a *real* cause for that disturbance will be found in the existence of another Planet beyond. But

* See Drinkwater's 'Life of Kepler,' in the Library of Useful Knowledge, pp. 26–35.

I trust that I have now made it evident to you, that this confident expectation is not justified by any absolute necessity of Nature, but arises entirely out of *our belief* in her Uniformity; and into the grounds of this and other Primary Beliefs, which serve as the foundation of all Scientific reasoning, we shall presently inquire.

There is another class of cases, in which an equal certainty is generally claimed for conclusions that seem to flow immediately from observed facts, though really evolved by Intellectual processes; the apparent simplicity and directness of those processes either causing them to be entirely overlooked, or veiling the assumptions on which they are based.—Thus Mr. Lockyer speaks as confidently of the Sun's Chromosphere of incandescent Hydrogen, and of the local outbursts which cause it to send forth projections tens of thousands of miles high, as if he had been able to capture a flask of this gas, and had generated water by causing it to unite with oxygen. Yet this confidence is entirely based on the assumption, that a certain line which is seen in the Spectrum of a hydrogen flame, *means* hydrogen also when seen in the spectrum of the Sun's chromosphere; and high as is the probability of that assumption, it cannot be regarded as a demonstrated certainty, since it is by no means inconceivable that the same line *might* be produced by *some other* substance at present unknown.—And so when Dr. Huggins deduces from the different relative positions of certain lines in the spectra of different Stars, that these Stars are moving from or towards us in space, his admirable train of reasoning is based on the assumption that these lines have *the same meaning* —that is, that they *represent the same elements*—in every luminary. That assumption, like the preceding, may be regarded as possessing a sufficiently high probability to justify the reasoning based upon it; more especially since, by the other researches of that excellent observer, the same Chemical elements have been detected as vapours in those filmy cloudlets which seem to be stars in an early stage of consolidation. But when Frankland and Lockyer, seeing in the spectrum of the yellow Solar prominences a certain bright line not identifiable with that of any known Terrestrial flame, attribute this to a hypothetical new substance which they propose to call Helium, it is obvious that their assumption rests on a far less secure foundation; until it shall have received that verification, which, in the case of Mr. Crookes's researches on Thallium, was afforded by the actual discovery of the new metal, whose presence had been indicated to him by a line in the Spectrum not attributable to any substance then known.

In a large number of other cases, moreover, our Scientific interpretations are clearly matters of *judgment*; and this is eminently a *personal act*, the value of its results depending in each case upon the qualifications of the *individual* for arriving at a correct decision. The surest of such judgments are those dictated by what we term "Common Sense," as to matters on which there seems no room for difference of opinion, because every sane person comes to the same conclusion, although he may be able to give no other reason for it than that it appears to him "self-evident." Thus while Philosophers have raised a thick cloud of dust in the discussion of the basis of our belief in the existence of a World external to ourselves,—of the Non Ego, as distinct from the Ego,—and while every Logician claims to have found some flaw in the proof advanced by every other,—the Common Sense of Mankind has arrived at a decision that is practically worth all the arguments of all the Philosophers who have fought again and again over this battle-ground. And I think it can be shown that the trustworthiness of this Common Sense decision arises from its dependence, not on any one set of

Experiences, but upon *our unconscious co-ordination of the whole aggregate of our Experiences*,—not on the conclusiveness of any one train of Reasoning, but on *the convergence of all our lines of thought towards this one centre.*

Now this "Common Sense," disciplined and enlarged by appropriate culture, becomes one of our most valuable instruments of Scientific inquiry; affording in many instances the best, and sometimes the only, basis for a rational conclusion. Let us take as a typical case, in which no special knowledge is required, what we are accustomed to call the "flint implements" of the Abbeville and Amiens gravel-beds. No logical proof can be adduced that the peculiar shapes of these flints were given to them by Human hands; but does any unprejudiced person now doubt it? The evidence of *design*, to which, after an examination of one or two such specimens, we should only be justified in attaching a probable value, derives an irresistible cogency from accumulation. On the other hand, the *im*probability that these flints acquired their peculiar shape by *accident*, becomes to our minds greater and greater as more and more such specimens are found; until at last this hypothesis, although it cannot be directly disproved, is felt to be almost inconceivable, except by minds previously "possessed" by the "dominant idea" of the modern origin of Man. And thus what was in the first instance a matter of discussion, has now become one of those "self-evident" propositions, which claim the unhesitating assent of all whose opinion on the subject is entitled to the least weight.

We proceed upwards, however, from such questions as the Common Sense of Mankind generally is competent to decide, to those in which special knowledge is required to give value to the judgment; and thus the interpretation of Nature by the use of that faculty comes to be more and more *individual*; things being perfectly "self-evident" to men of special culture, which ordinary men, or men whose training has lain in a different direction, do not apprehend as such. Of all departments of Science, Geology seems to me to be the one that most depends on this specially-trained "Common Sense;" which brings as it were into one focus the light afforded by a great variety of studies,—Physical and Chemical, Geographical and Biological; and throws it on the pages of that Great Stone Book, on which the past history of our Globe is recorded. And whilst Astronomy is of all Sciences that which may be considered as most nearly representing Nature as she really is, Geology is that which most completely represents her as seen through the medium of the interpreting mind; the meaning of the phenomena that constitute its data being in almost every instance open to question, and the judgments passed upon the same facts being often different according to the qualifications of the several judges. No one who has even a general acquaintance with the history of this department of Science, can fail to see that the Geology of each epoch has been the reflection of the Minds by which its study was then directed; and that its true progress dates from the time when that "Common Sense" method of interpretation came to be *generally* adopted, which consists in seeking the explanation of past changes in the Forces at present in operation, instead of invoking the aid of extraordinary and mysterious agencies, as the older Geologists were wont to do, whenever they wanted—like the Ptolemaic Astronomers—"to save appearances." The whole tendency of the ever-widening range of modern Geological inquiry has been to show how little reliance can be placed upon the so-called "Laws" of Stratigraphical and Palæontological Succession, and how much allowance has to be made for local conditions. So that while the Astronomer is constantly enabled to point to the fulfilment of his predictions as an

evidence of the correctness of his method, the Geologist is almost entirely destitute of any such means of verification. For the value of any prediction that he may hazard—as in regard to the existence or non-existence of Coal in any given area,—depends not only upon the truth of the general doctrines of Geology in regard to the succession of Stratified Deposits, but still more upon the detailed knowledge which he may have acquired of the distribution of those Deposits in the particular locality. Hence no reasonably-judging man would discredit either the general doctrines or the methods of Geology, because the prediction proves untrue in such a case as that now about to be brought in this neighbourhood to the trial of experience.

We have thus considered Man's function as the Scientific Interpreter of Nature in two departments of Natural Knowledge; one of which affords an example of the strictest, and the other of the freest method, which Man can employ in constructing his Intellectual representation of the Universe. And as it would be found that in the study of all other departments the same methods are used, either separately or in combination, we may pass at once to another part of our inquiry.

The whole fabric of Geometry rests upon certain Axioms which every one accepts as true, but of which it is necessary that the truth should be *assumed*, because they are incapable of demonstration. So, too, the deliverances of our "Common Sense" derive their trustworthiness from what we consider the "self-evidence" of the propositions affirmed. There are, then, certain Primary Beliefs, which constitute the groundwork of all Scientific reasoning; and we have next to inquire into their origin.

This inquiry brings us face to face with one of the great Philosophical problems of our day, which has been discussed by Logicians and Metaphysicians of the very highest ability as Leaders of opposing Schools, with the one result of showing how much can be said on each side. By the *Intuitionalists* it is asserted that the tendency to form these Primary Beliefs is inborn in Man, an original part of his mental organization; so that they grow up spontaneously in his Mind as its faculties are gradually unfolded and developed, requiring no other Experience for their genesis, than that which suffices to call these faculties into exercise. But by the advocates of the doctrine which regards *Experience* as the basis of all our knowledge, it is maintained that the Primary Beliefs of each individual are nothing else than generalizations which he forms of such experiences as he has either himself acquired or has consciously learned from others; and they deny that there is any original or intuitive tendency to the formation of such beliefs, beyond that which consists in the power of retaining and generalizing experiences.

I have not introduced this subject with any idea of placing before you even a summary of the ingenious arguments by which these opposing doctrines have been respectively supported; nor should I have touched on the question at all, if I did not believe that a means of reconcilement between them can be found in the idea, that *the Intellectual Intuitions of any one Generation are the embodied Experiences of the previous Race.* For, as it appears to me, there has been a progressive improvement in the *Thinking Power* of Man; every product of the culture which has preceded serving to prepare the soil for yet more abundant harvests in the future.

Now, as there can be no doubt of the Hereditary transmission in Man of acquired constitutional peculiarities, which manifest themselves alike in tendencies to Bodily and to Mental disease, so it seems equally certain that *acquired mental habitudes* often impress themselves on his organization, with

sufficient force and permanence to occasion their transmission to the offspring as *tendencies to similar modes of thought*. And thus, while all admit that *Knowledge* cannot thus descend from one generation to another, an increased *aptitude* for the acquirement, either of knowledge generally, or of some particular kind of it, may be thus inherited. These tendencies and aptitudes will acquire additional strength, expansion, and permanence, in each new generation, from their habitual exercise upon the materials supplied by a continually enlarged experience; and thus the *acquired* habitudes produced by the Intellectual culture of ages, will become "a second nature" to every one who inherits them *.

We have an illustration of this progress in the fact of continual occurrence, that conceptions which prove inadmissible to the minds of one generation, in consequence either of their want of intellectual power to apprehend them, or of their preoccupation by older habits of thought, subsequently find a universal acceptance, and even come to be approved as "self-evident." Thus the First Law of Motion, divined by the genius of Newton, though opposed by many Philosophers of his time as contrary to all experience, is now accepted by common consent, not merely as a legitimate inference from Experiment, but as the expression of a necessary and universal truth; and the same Axiomatic value is extended to the still more general doctrine, that Energy of *any* kind, whether manifested in the "molar" motion of masses, or consisting in the "molecular" motion of atoms, *must* continue under some form or other without abatement or decay; what all admit in regard to the indestructibility of Matter, being accepted as no less true of Force, namely, that as *ex nihilo nil fit*, so *nil fit ad nihilum* †.

But, it may be urged, the very conception of these and similar great truths is in itself a typical example of Intuition. The men who divined and enunciated them stand out above their fellows, as possessed of a Genius which could not only combine but create, of an Insight which could clearly discern what Reason could but dimly shadow forth. Granting this freely, I think it may be shown that the Intuitions of individual Genius are but specially exalted forms of endowments which are the general property of the Race at the time, and which have come to be so in virtue of its whole previous culture.—Who, for example, could refuse to the marvellous aptitude for perceiving the relations of Numbers, which displayed itself in the untutored boyhood of George Bidder and Zerah Colburn, the title of an Intuitive gift? But who, on the other hand, can believe that a Bidder or a Colburn could suddenly

* This doctrine was first explicitly put forth by Mr. Herbert Spencer; in whose Philosophical Treatises it will be found most ably developed. I am glad to be able to append the following extract from a letter which Mr. John Mill, the great Master of the Experiential School, was good enough to write to me a few months since, with reference to the attempt I had made to place "Common Sense" upon this basis (Contemporary Review, Feb. 1872):—"When states of mind in no respect innate or instinctive have been "frequently repeated, the mind acquires, as is proved by the power of Habit, a greatly "increased facility of passing into those states; and this increased facility must be owing "to some change of a physical character in the organic action of the Brain. There is also "considerable evidence that such acquired facilities of passing into certain modes of "cerebral action can in many cases be transmitted, more or less completely, by inheritance. "The limits of this power of transmission, and the conditions on which it depends, are a "subject now fairly before the scientific world; and we shall doubtless in time know much "more about them than we do now. But so far as my imperfect knowledge of the subject "qualifies me to have an opinion, I take much the same view of it that you do, at least "in principle."

† This is the form in which the doctrine now known as that of the "Conservation of Energy" was enunciated by Dr. Mayer, in the very remarkable Essay published by him in 1845, entitled "Die organische Bewegung in ihrem Zusammenhange mit dem Stoffwechsel."

arise in a race of Savages who cannot count beyond five? Or, again, in the history of the very earliest years of Mozart, who can fail to recognize the dawn of that glorious Genius, whose brilliant but brief career left its imperishable impress on the Art it enriched? But who would be bold enough to affirm that an infant Mozart could be born amongst a tribe, whose only musical instrument is a tom-tom, whose only song is a monotonous chant?

Again, by tracing the gradual *genesis* of some of those Ideas which we now accept as "self-evident,"—such, for example, as that of the "Uniformity of Nature"—we are able to recognize them as the expressions of certain Intellectual tendencies, which have progressively augmented in force in successive generations, and now manifest themselves as acquired Mental Instincts that penetrate and direct our ordinary course of Thought. Such Instincts constitute a precious heritage, which has been transmitted to us with ever-increasing value through the long succession of preceding generations; and which it is for us to transmit to those who shall come after us, with all that further increase which our higher Culture and wider range of Knowledge can impart.

And now, having studied the working action of the Human Intellect in the Scientific Interpretation of Nature, we shall examine the general character of its products; and the first of these with which we shall deal is our conception of *Matter* and of its relation to *Force*.

The Psychologist of the present day views Matter entirely through the light of his own Consciousness: his idea of Matter in the abstract being that it is a "something" which has a permanent power of exciting Sensations; his idea of any "property" of Matter being the mental representation of some kind of sensory impression he has received from it; and his idea of any particular kind of Matter being the representation of the whole aggregate of the Sense-perceptions which its presence has called up in his Mind. Thus when I press my hand against this table, I recognize its unyieldingness through the conjoint medium of my sense of Touch, my Muscular sense, and my Mental sense of Effort, to which it will be convenient to give the general designation of the Tactile Sense; and I attribute to that table a *hardness* which resists the effort I make to press my hand into its substance, whilst I also recognize the fact that the force I have employed is not sufficient to move its mass. But I press my hand against a lump of dough; and finding that its substance yields under my pressure, I call it *soft*. Or again, I press my hand against this desk; and I find that although I do not thereby change its *form*, I change its *place*; and so I get the Tactile idea of *Motion*. Again, by the impressions received through the same Sensorial apparatus, when I lift this book in my hand, I am led to attach to it the notion of *weight* or ponderosity; and by lifting different solids of about the same size, I am enabled, by the different degrees of exertion I find myself obliged to make in order to sustain them, to distinguish some of them as *light*, and others as *heavy*. Through the medium of another set of Sense-perceptions which some regard as belonging to a different category, we distinguish between bodies that *feel* "hot" and those that *feel* "cold;" and in this manner we arrive at the notion of differences of Temperature. And it is through the medium of our Tactile Sense, without any aid from Vision, that we first gain the idea of *solid form*, or the Three Dimensions of Space.

Again, by the extension of our Tactile experiences, we acquire the notion of *liquids*, as forms of matter yielding readily to pressure, but possessing a sensible weight which may equal that of solids: and of *air*, whose resisting power is much slighter, and whose weight is so small that it can only be made sensible by artificial means. Thus, then, we arrive at the notions of

resistance and of *weight* as properties common to all forms of Matter; and now that we have got rid of that idea of Light and Heat, Electricity and Magnetism, as "imponderable fluids," which used to vex our souls in our Scientific Childhood, and of which the popular term "Electric fluid" is a "survival," we accept these properties as affording the practical distinction between the "material" and the "immaterial."

Turning, now, to that other great portal of Sensation, the Sight, through which we receive most of the messages sent to us from the Universe around, we recognize the same truth. Thus it is agreed alike by Physicists and Physiologists, that *Colour* does not exist *as such* in the object itself; which has merely the power of reflecting or transmitting a certain number of millions of undulations in a second; and these only produce that affection of our consciousness which we call Colour, when they fall upon the retina of the living Percipient. And if there be that defect either in the retina or in the apparatus behind it, which we call "colour-blindness" or Daltonism, some particular hues cannot be distinguished, or there may even be no power of distinguishing any colour whatever. If we were all like Dalton, we should see no difference, except in form, between ripe cherries hanging on a tree, and the green leaves around them: if we were all affected with the severest form of colour-blindness, the fair face of Nature would be seen by us as in the chiaroscuro of an Engraving of one of Turner's Landscapes, not as in the glowing hues of the wondrous Picture itself. And in regard to our Visual conceptions it may be stated with perfect certainty, as the result of very numerous observations made upon persons who have acquired sight for the first time, that these do *not* serve for the recognition even of those objects with which the individual had become most familiar through the Touch, until the two sets of Sense-perceptions have been co-ordinated by experience*.

When once this co-ordination has been effected, however, the composite perception of Form which we derive from the Visual sense alone is so complete, that we seldom require to fall back upon the Touch for any further information respecting that quality of the object.—So, again, while it is from the co-ordination of the two dissimilar pictures formed by any solid or projecting object upon our two retinæ, that (as Sir Charles Wheatstone's admirable investigations have shown) we ordinarily derive through the Sight alone a correct notion of its *solid* form, there is adequate evidence that this notion, also, is a mental *judgment* based on the experience we have acquired in early infancy by the consentaneous exercise of the Visual and Tactile senses.

Take, again, the case of those wonderful instruments by which our Visual range is extended almost into the infinity of Space, or into the infinity of Minuteness. It is the mental not the bodily eye, that takes cognizance of what the Telescope and the Microscope reveal to us. For we should have no well-grounded confidence in their revelations as to the *unknown*, if we had not first acquired experience in distinguishing the true from the false by applying them to *known* objects; and every interpretation of what we see through their instrumentality is a *mental judgment* as to the probable form,

* Thus, in a recently recorded case in which sight was imparted by operation to a young woman who had been blind from birth, but who had nevertheless learned to work well with her needle, when the pair of scissors she had been accustomed to use was placed before her, though she described their shape, colour, and glistening metallic character, she was utterly unable to recognize them *as scissors* until she put her finger on them, when she at once named them, laughing at her own stupidity (as she called it) in not having made them out before.

size, and movement of bodies removed by either their distance or their minuteness from being cognosced by our Tactile Sense.

The case is still stronger in regard to that last addition to our Scientific *armamentum*, which promises to be not inferior in value either to the Telescope or the Microscope; for it may be truly said of the Spectroscope, that it has not merely extended the range of our Vision, but has almost given us a new sense, by enabling us to recognize distinctive properties in the Chemical Elements which were previously quite unknown. And who shall now say that we know all that is to be known as to any form of Matter; or that the Science of the *fourth* quarter of this century may not furnish us with as great an enlargement of our knowledge of its Properties, and of our power of recognizing them, as that of its *third* has done?

But, it may be said, is not this view of the Material Universe open to the imputation that it is "evolved out of the depths of our own consciousness"—a projection of our own Intellect into what surrounds us—an *ideal* rather than a *real* World? If all we know of Matter be an "Intellectual Conception," how are we to distinguish this from such as we form in our Dreams?—for these, as our Laureate no less happily than philosophically expresses it, are "true while they last." Here our "Common Sense" comes to the rescue. We "awake, and behold it was a dream." Every healthy mind is conscious of the difference between its waking and its dreaming experiences; or, if it is now and then puzzled to answer the question "Did this really happen, or did I dream it?" the perplexity arises from the consciousness that it *might* have happened. And every healthy mind, finding its own experiences of its waking state not only self-consistent, but consistent with the experiences of others, accepts them as the basis of its beliefs, in preference to even the most vivid recollections of its dreams.

The Lunatic Pauper who regards himself as a King, the Asylum in which he is confined as a Palace of regal splendour, and his Keepers as obsequious attendants, is so "possessed" by the conception framed by his disordered intellect, that he *does* project it out of himself into his surroundings; his refusal to admit the corrective teaching of Common Sense being the very essence of his malady. And there are not a few persons abroad in the world, who equally resist the teachings of Educated Common Sense, whenever they run counter to their own preconceptions; and who may be regarded as—in so far—affected with what I once heard Mr. Carlyle pithily characterize as a "diluted Insanity."

It has been asserted, over and over again, of late years, by a class of men who claim to be the only true Interpreters of Nature, that we know nothing but Matter and the Laws of Matter, and that Force is a mere fiction of the Imagination. May it not be affirmed, on the other hand, that while our notion of *Matter* is a Conception of the Intellect, *Force* is that of which we have the *most* direct—perhaps even the *only* direct—cognizance? As I have already shown you, the knowledge of Resistance and of Weight which we gain through our Tactile Sense is derived from our own perception of *exertion*; and in Vision, as in Hearing, it is the Force with which the undulations strike the sensitive surface, that affects our consciousness with Sights or Sounds. True it is that in our Visual and Auditory Sensations, we do not, as in our Tactile, *directly* cognosce the Force which produces them; but the Physicist has no difficulty in making sensible to us indirectly the undulations by which Sound is propagated, and in proving to our Intellect that the Force concerned in the transmission of Light is really enormous*.

* See Sir John Herschel's Familiar Lectures on Scientific Subjects.

It seems strange that those who make the loudest appeal to Experience as the basis of all knowledge, should thus disregard the most constant, the most fundamental, the most direct of all experiences; as to which the Common Sense of Mankind affords a guiding light much clearer than any that can be seen through the dust of Philosophical discussion. For, as Sir John Herschel most truly remarked, the universal Consciousness of mankind is as much in accord in regard to the existence of a real and intimate connexion between Cause and Effect, as it is in regard to the existence of an External World; and that consciousness arises to every one out of his own sense of *personal* exertion in the origination of changes by his individual agency.

Now while fully accepting the Logical definition of Cause as the "antecedent or concurrence of antecedents on which the Effect is invariably and unconditionally consequent," we can always single out one *dynamical* antecedent—the Power which does the work—from the aggregate of *material conditions* under which that Power may be distributed and applied. No doubt the term Cause is very loosely employed in popular phraseology; often (as Mr. Mill has shown) to designate the occurrence that immediately preceded the effect;—as when it is said that the spark which falls into a barrel of gunpowder is the cause of its explosion, or that the slipping of a man's foot off the rung of a ladder is the cause of his fall. But even a very slightly trained Intelligence can distinguish the Power which acts in each case, from the Conditions under which it acts. The Force which produces the explosion is locked up (as it were) in the powder; and ignition merely liberates it, by bringing about new Chemical combinations. The fall of the man from the ladder is due to the Gravity which was equally pulling him down while he rested on it; and the loss of support, either by the slipping of his foot, or by the breaking of the rung, is merely that change in the material conditions which gives the Power a new action.

Many of you have doubtless viewed with admiring interest that truly wonderful work of Human Design, the Walter Printing Machine. You first examine it at rest; presently comes a man who simply pulls a handle towards him; and the whole inert mechanism becomes instinct with life,—the continuous sheet of four miles of blank paper which rolls off the cylinder at one end, being delivered at the other, without any intermediate human agency, as separate "Times" Newspapers, at the rate of 15,000 an hour. Now what is the *Cause* of this most marvellous effect? Surely it lies essentially in the Power or Force which the pulling of the handle brought to bear on the machine from some extraneous source of Power,—which we in this instance know to be a Steam-engine on the other side of the wall. This Force it is, which, distributed through the various parts of the Mechanism, really performs the action of which each is the instrument; *they* only supply the vehicle for its transmission and application. The man comes again, pushes the handle in the opposite direction, detaches the Machine from the Steam-engine, and the whole comes to a stand; and so it remains, like an inanimate corpse, until recalled to activity by the renewal of its Moving Power.

But, say the Reasoners who deny that Force is any thing else than a fiction of the imagination, the revolving shaft of the Steam-engine is "Matter in Motion;" and when the connexion is established between that shaft and the one that drives the Machine, the *Motion* is communicated from the former to the latter, and thence distributed to the several parts of the Mechanism. This account of the operation is just what an observer might give, who had looked-on with entire ignorance of every thing but what his *eyes* could *see*; the moment he puts his *hand* upon any part of the machinery, and tries to

stop its motion, he takes as direct cognizance, through his *feeling* of the Effort required to resist it, of the *force* which produces that motion, as he does through his *eye* of the motion itself.

Now since it is universally admitted that our notion of the External World would be not only incomplete, but erroneous, if our Visual perceptions were not supplemented by our Tactile, so, as it seems to me, our interpretation of the Phenomena of the Universe must be very inadequate, if we do not mentally co-ordinate the idea of Force with that of Motion, and recognize it as the "efficient cause" of those phenomena,—the "material conditions" constituting (to use the old Scholastic term) only "their formal cause." And I lay the greater stress on this point, because the Mechanical Philosophy of the present day tends more and more to express itself in terms of *Motion* rather than in terms of *Force*;—to become *Kinetics* instead of *Dynamics*.

Thus from whatever side we look at this question,—whether the Common Sense of Mankind, the Logical Analysis of the relation between Cause and Effect, or the Study of the working of our own Intellects in the interpretation of Nature,—we seem led to the same conclusion; that the notion of *Force* is one of those elementary Forms of Thought with which we can no more dispense, than we can with the notion of Space or of Succession. And I shall now, in the last place, endeavour to show you that it is the substitution of the Dynamical for the mere Phenomenal idea, which gives their highest value to our conceptions of that Order of Nature, which is worshipped as itself a God by the class of Interpreters whose doctrine I call in question.

The most illustrative as well as the most illustrious example of the difference between the mere Generalization of Phenomena and the Dynamical conception that applies to them, is furnished by the contrast between the so-called Laws of Planetary Motion discovered by the persevering ingenuity of Kepler, and the interpretation of that Motion given us by the profound insight of Newton. Kepler's three Laws were nothing more than comprehensive statements of certain groups of Phenomena determined by observation. The *first*, that of the revolution of the Planets in Elliptical orbits, was based on the study of the observed places of Mars alone; it might or might not be true of the other Planets; for, so far as Kepler knew, there was no reason why the orbits of some of them might not be the excentric circles which he had first supposed that of Mars to be. So Kepler's *second* law of the passage of the Radius Vector over equal areas in equal times, so long as it was simply a generalization of facts in the case of that one Planet, carried with it no *reason* for its applicability to other cases, except that which it might derive from his erroneous conception of a whirling force. And his *third* law was in like manner simply an expression of a certain Harmonic relation which he had discovered between the times and the distances of the Planets, having no more *rational* value than any other of his numerous hypotheses.

Now the Newtonian "Laws" are often spoken of as if they were merely *higher generalizations* in which Kepler's are included; to me they seem to possess an altogether different character. For starting with the Conception of two *Forces*, one of them tending to produce continuous uniform motion in a straight line, the other tending to produce a uniformly accelerated motion towards a fixed point, Newton's wonderful mastery of Geometrical reasoning enabled him to show that, if these *Dynamical* assumptions be granted, Kepler's *phenomenal* "Laws," being necessary consequences of them, must be *universally* true. And while that demonstration would have been alone

sufficient to give him an imperishable renown, it was his still greater glory to divine that the fall of the Moon towards the Earth—that is, the deflection of her path from a tangential line to an ellipse—*is a phenomenon of the same order* as the fall of a stone to the ground; and thus to show the applicability to the entire Universe, of those simple Dynamical conceptions which constitute the basis of the Geometry of the Principia.

Thus, then, whilst no "Law" which is simply *a generalization of Phenomena* can be considered as having any *coercive* action, we may assign that value to Laws which express *the universal conditions of the action of a Force* whose existence we learn from the testimony of our own consciousness. The assurance we feel that the Attraction of Gravitation *must* act under all circumstances according to those simple Laws which arise immediately out of our Dynamical conception of it, is of a very different order from that which we have in regard (for example) to the Laws of Chemical Attraction, which are as yet only generalizations of phenomena. And yet even in that strong assurance, we are required by our examination of the basis on which it rests, to admit a *reserve* of the *possibility* of something different; a reserve which we may well believe that Newton himself must have entertained.

A most valuable lesson as to the allowance we ought always to make for the unknown "possibilities of Nature," is taught us by an exceptional phenomenon so familiar that it does not attract the notice it has a right to claim. Next to the Law of the Universal Attraction of Masses of Matter, there is none that seems to have a wider range than that of the *Expansion of Bodies by Heat and their Contraction by Cold.* Excluding Water and one or two other substances, the fact of such expansion might be said to be *invariable*; and, as regards bodies whose Gaseous condition is known, the Law of Expansion can be stated in a form no less simple and definite than the Law of Gravitation. Supposing those exceptions, then, to be unknown, the Law would be *universal* in its range. But it comes to be discovered that Water, whilst conforming to it in its expansion from $39\frac{1}{2}°$ *upwards* to its boiling-point, as also, when it passes into Steam, to the special law of Expansion of Vapours, is exceptional in *expanding* also from $39\frac{1}{2}°$ *downwards* to its Freezing-point; and of this failure in the Universality of the Law, no rationale can be given. Still more strange is it, that by dissolving a little *salt* in water, we should remove this exceptional peculiarity; for *sea*-water continues to contract from $39\frac{1}{2}°$ downwards to its Freezing-point 12° or 14° lower, just as it does with reduction of temperature at higher ranges.

Thus from our study of the mode in which we arrive at those conceptions of the Orderly Sequence observable in the Phenomena of Nature which we call "Laws," we are led to the conclusion that they are Human conceptions, subject to Human fallibility; and that they *may* or *may not* express the Ideas of the Great Author of Nature. To set up these Laws as self-acting, and as either excluding or rendering unnecessary the Power which alone can give them effect, appears to me as arrogant as it is unphilosophical. To speak of *any* Law as "regulating" or "governing" phenomena, is only permissible on the assumption that the Law is the expression of the *modus operandi* of a Governing Power.—I was once in a great City which for two days was in the hands of a lawless mob. Magisterial authority was suspended by timidity and doubt; the force at its command was paralyzed by want of resolute direction. The "Laws" were on the Statute book, but there was no Power to enforce them. And so the Powers of evil did their terrible work; and fire and rapine continued to destroy life and property without check, until new Power came in, when the Reign of Law was restored.

And thus we are led to the culminating point of Man's Intellectual Interpretation of Nature,—his recognition of the Unity of the Power, of which her Phenomena are the diversified manifestations. Towards this point all Scientific inquiry now tends. The Convertibility of the Physical Forces, the Correlation of these with the Vital, and the intimacy of that *nexus* between Mental and Bodily activity, which, explain it as we may, cannot be denied, all lead upward towards one and the same conclusion; and the pyramid of which that Philosophical conclusion is the apex, has its foundation in the Primitive Instincts of Humanity.

By our own remote Progenitors, as by the untutored Savage of the present day, every change in which Human agency is not apparent was referred to a particular Animating Intelligence. And thus they attributed not only the movements of the Heavenly bodies, but all the phenomena of Nature, each to its own Deity. These Deities were invested with more than Human power; but they were also supposed capable of Human passions, and subject to Human capriciousness. As the Uniformities of Nature came to be more distinctly recognized, some of these Deities were invested with a dominant control, while others were supposed to be their subordinate ministers. A serene Majesty was attributed to the greater Gods who sit above the clouds; whilst their inferiors might "come down to Earth in the likeness of Men." With the growth of the Scientific Study of Nature, the conception of its Harmony and Unity gained ever-increasing strength. And so among the most enlightened of the Greek and Roman Philosophers, we find a distinct recognition of the idea of the Unity of the Directing Mind from which the Order of Nature proceeds; for they obviously believed that, as our modern Poet has expressed it,—

> "All are but parts of one stupendous whole,
> "Whose body Nature is, and God the Soul."

The Science of Modern times, however, has taken a more special direction. Fixing its attention exclusively on the *Order* of Nature, it has separated itself wholly from Theology, whose function it is to seek after its *Cause*. In this, Science is fully justified, alike by the entire independence of its objects, and by the historical fact that it has been continually hampered and impeded in its search for the Truth as it is in Nature, by the restraints which Theologians have attempted to impose upon its inquiries. But when Science, passing beyond its own limits, assumes to take the place of Theology, and sets up its own conception of the *Order* of Nature as a sufficient account of its *Cause*, it is invading a province of Thought to which it has no claim, and not unreasonably provokes the hostility of those who ought to be its best friends.

For whilst the deep-seated instincts of Humanity, and the profoundest researches of Philosophy, alike point to Mind as the one and only source of Power, it is the high prerogative of Science to demonstrate the *Unity* of the Power which is operating through the limitless extent and variety of the Universe, and to trace its *Continuity* through the vast series of Ages that have been occupied in its Evolution.

REPORTS

ON

THE STATE OF SCIENCE.

Report on the Gaussian Constants for the year 1829, *or a Theory of Terrestrial Magnetism founded on all available observations. By* H. PETERSEN *and* A. ERMAN.

IT was in 1838 that the illustrious C. F. Gauss published the principles of a method which made all the phenomena of terrestrial magnetism as fully calculable as are astronomical phenomena by Newton's theory of gravitation. This beautiful accession to natural philosophy may be summed up as follows:—

For every point of space, the position of which is given by its distance r from the earth's centre, and by the angles u and λ denoting respectively its angular distance from the geographical north pole and its longitude east from Greenwich, there exists a mathematical expression relating to the terrestrial magnetic qualities of this point, and containing only r and trigonometrical functions of u and λ, together with numerical values that are the same for the whole extent of space. This expression is called the magnetic potential of the point; and as to the said numerical values, we give them here, as we did in the Report on our computation made during the years 1846 to 1848, the name of the Gaussian Constants. This must be understood as relating to their invariability as to space, but by no means to independence of time.

For every point on the earth's surface, or above it, up to infinite distance, the magnetic potential has a finite value, and in consequence thereof must be calculable as soon as the Gaussian constants are known. There exists no visible or measurable phenomenon which for every given point agrees with the value of the magnetic potential; but this remarkable quantity is for every place in explicit connexion with the intensity and the direction of the magnetic force which is exerted there by the causes considered. These two measurable phenomena are therefore given as soon as the potential can be ascertained; and the same is the case with every one of the components which we are wont to form of terrestrial magnetism for the sake of easier observations—as, for instance, with the three rectangular components, which in their turn are equivalent to the horizontal and vertical intensities and to

what we call the angles of declination and inclination. Indeed at any place a component in any direction whatever of the magnetic force is merely proportional to the increment which the potential there takes by a small displacement in the same direction. But now the determination of that potential which outside a sphere results from any magnetic actions of its interior, and therefore, according to the last remark, the foretelling of all magnetic phenomena produced by the same causes, become possible and are facilitated by the following circumstances. In every case of the description just mentioned the magnetic potential can be expanded into an infinite but converging series, proceeding by integer powers of $\frac{1}{r}$, the exponent of the first one being $+1$. Among the terms of this series, that which is divided

by r	contains 3	of the Gaussian	constants,
r^2	5	,,	,,
r^3	7	,,	,,
$\vdots$	$\vdots$		
r^n	$2n+1$	,,	,,

In the formula for the potential, each of these constants is multiplied by a theoretically given trigonometrical function of u and λ, and therefore, for any given point, by the numerical equivalent of this function. The algebraic developments which Gauss's classical work contains for the magnetic potential, as well as for the observable magnetic components, relate also to the actions of a sphere enclosing a finite or infinite number of any magnetic centres whatsoever. Therefore these expressions can represent our terrestrial phenomena only after the substitution, for every symbol denoting a Gaussian constant, of that number which the individual magnetic qualities of the earth require, according to observations. But then, specially, this transformation of the abstract theory of the magnetic actions of a sphere into the practical theory of terrestrial magnetism will amount to the determination, from a sufficient number of observed values, of 15, 24, 35, or generally n^2+2n Gaussian constants, according as it appears that the third, the fourth, the fifth, or generally the nth term in the algebraical expressions of these empirical data is the first that is surpassed by the probable amount of their inevitable errors.

A first attempt towards the completion of the theory of terrestrial magnetism was made by its illustrious author with material of which the gaps for the greater part of the Antarctic Ocean, and for other vast regions, could only be filled up by graphical guesswork. It led to the conclusion that a restriction to four terms of the potential, and therefore the determination of 24 Gaussian constants, did more than respond to the mean exactitude of the empirical data. To the same effect was the computation that H. Petersen executed from 1846 to 1848, when commissioned for the purpose by the British Association. Indeed, it being exclusively founded on 610 results of careful magnetic measurements made by A. Erman on a line round the earth between 67° north latitude and 60° south latitude, the resulting new constants represented these observed values fully twice as well as did the old ones, and thereby, as must be avowed, up to the amount of their own probable errors. But it having been shown by later experience that, just as was expected, much larger disagreement between reality and both the theoretical deductions, did still exist in those parts of the earth where the one or the

other had wanted empirical supplementing*; and we, in consequence thereof undertaking the recomputation now finished with all available observations, resolved once more to confine ourselves to the determination of the same 24 constants solely. Indeed the material on which we have founded this new and definitive calculation is by its geographical completeness far superior to that of both the former ones; but many of its modern accessions do not exceed, nor even attain the exactitude of the observations mentioned above.

According to what we have stated in the beginning, the Gaussian constants must to the same extent be either dependent on or independent of time as are the phenomena of terrestrial magnetism. Now very old and indubitable experience has proved that each of these phenomena undergoes not only the various short-period changes, from which the observer can easily, and is always supposed to free them, but also the so-called secular variations of by far a larger amount. The Gaussian constants being then likewise variable as to time, it appears that they can be determined each time but for one given epoch, and then out of observations which either have been all made at this epoch, or reduced to what they would have given if made at the same.

The aim of our present calculations was to determine with all attainable exactitude the Gaussian constants for the year 1829, in order that the results of the newly founded theory might be directly comparable as well with those of their first evaluation, relating nearly to the same epoch, as with the most careful measurements made by Hansteen and Erman between 1828 and 1830. But, as for carrying this out we had to make an equal use of all observations to be relied upon, and originating whether in the selected epoch or at any interval whatsoever before or after this time, our work was divided into two independent parts:—

1. Formulæ were to be constructed and employed for reducing each of the magnetic results which, at widely differing times, had been obtained by observations all over the earth's surface, to what they would have been in 1829; and
2. Out of these reduced values, twenty-four numbers were to be computed which, when taken for our twenty-four Gaussian constants, responded as nearly as possible to all empirical data observed in, or reduced to, the epoch 1829.

I. *Reduction of Observed Values to the Year* 1829.

Without the existence of the Gaussian theory, the only means to execute such reductions would have been, for every kind of magnetic phenomena at any place, to guess what changes they had undergone, according to the changes which had been observed for the same phenomena at certain other places. Such rude attempts have indeed been made for the purpose of ascertaining the changes of declination at places where they had never been observed. They could perhaps have been extended, though with much less foundation on experience, to inclination-changes; whereas for the secular variations of intensity not even this appearance of a means existed, owing to an almost total want of data. But the problem of our reductions has now

* As, for instance, according to the comparison made by A. Erman, between the results of both systems of constants and the magnetic observations at some places in India, by Mr. K. Koppe, who was commissioned to do so in the Total-Eclipse Expedition of 1868, as published in the 'Astronomische Nachrichten,' vol. lxxv. p. 242 *et seq.*

been stated in proper form and has been greatly simplified, since theory has shown that, and how, all kinds of magnetic secular changes, for any arbitrary time and place, depend on one common cause, viz. on the synchronous changes of the Gaussian constants. Indeed these quantities only can give to the algebraic expressions of magnetic elements different numerical values at various epochs, because the quantities r, u, and λ are by their nature once and for ever invariable; and then, as only the first power of every Gaussian constant, and no products of them, occurs in the potential, the following general rule can evidently be laid down:—The amount of change for any element of terrestrial magnetism (as, for instance, for the declination, the inclination, one of the three rectangular components, and so forth) during a given period must be calculated by that same formula which expresses its absolute value, if only instead of each Gaussian constant there is placed the increment which its value has received during the same period. This plain corollary of the magnetic theory has been of twofold use for the reductions we had to make, and will serve in the same way for all future ones. Indeed its inverse application gives, from observed changes of magnetic phenomena, the synchronous changes of the Gaussian constants; and by substituting these latter results in the direct formulæ, the changes of every phenomenon may be computed for places where they have never been observed. The first part of this proceeding is immensely preferable to empirical guessings; for it makes an almost equal use of the variations in any kind of magnetic phenomena, and thereby leads to the knowledge of these variations in those kinds for which experience is wanting. The secular changes of intensity may therefore be ascertained for periods in which we know only changes of inclination and declination, or even for those in which the latter only have been observed. Moreover it is only by these means that the consequences of experience on secular changes in certain parts of the earth can very confidently be extended to the remotest parts.

Nevertheless, before we could make the application of this memorable method, a decision was wanted concerning two points, according to the result of which our proposed reductions might prove to be either easy or difficult, or even wholly impracticable; to wit:—

1. What kind of connexion exists between the lapse of time and the variations which are undergone by magnetic phenomena and consequently by the Gaussian constants? and
2. In how many and in which of the Gaussian constants will the variations be of most influence, and in which others may they be neglected for practical approximation?

As to the first question, it has been proved by the changes of the three magnetic components at Berlin, observed fully during the last forty-five years by Erman, and partially at intervals during almost a hundred years by others, and besides by a great number of partial series of observations at other places, that during the last century the variations of magnetic phenomena, and consequently those of the Gaussian constants, have never happened by a leap, but have always progressed according to the law of continuity, and especially so that their amount has been merely proportional to the lapse of time and to its square. If, therefore, the increment of one of these constants from a year denoted by T′ to another denoted by T has been ascertained, the $\left(\frac{1}{T-T'}\right)$th of this quantity will be equal to the annual increase of the same constant for the year denoted by $\frac{T+T'}{2}$. More-

over it follows that, by the knowledge of such annual increase at two moments separated from one another by a sufficiently long space of time, we can calculate not only its value for any moment, but also that of the corresponding total increase during any period. Therefore the materials we possessed (as is to be shown hereafter) for computing the annual increments of the constants for the year 1811 and for the year 1843·5, must suffice for our reductions; but before employing them we had to consider the second of the above-mentioned questions. An indubitable answer to it was, of course, that we had to take into account and to determine the variation with time for all those twenty-four constants the values of which were to be determined afterwards by the reduced observations. The solution of the problem up to this highest degree of exactitude will at some future time be a beautiful result of our present work, combined with a similar one for a later date; but had we undertaken it now, the preparatory task would not only have become more extensive than the essential one, but would even have been impeded by a most sensible want of means. We had therefore to content ourselves with making our reductions for secular changes an approximation to reality, in the same way as astronomers do when, in computing secular planetary perturbations, they disregard the terms of less influence. So in this particular case it was resolved to take into consideration only the changes of the first two terms of the potential—that is to say, to ascertain for two epochs the annual increments of the first eight of the Gaussian constants.

A. *On the Equations for annual Increments of Constants during the year* 1811.

In order to ascertain the amount of the annual changes of the Gaussian constants marked by

$$g^{1\cdot 0},\ g^{1\cdot 1},\ h^{1\cdot 1},\ g^{2\cdot 0},\ g^{2\cdot 1},\ h^{2\cdot 1},\ g^{2\cdot 2},\ \text{and}\ h^{2\cdot 2}$$

for our first epoch of 1811, we have founded the computation on :—

1. The increments of declination which appear as having happened from the year 1784 to the year 1840, from a comparison of the maps of isogonic lines constructed for the said years by C. Hansteen and E. Sabine ; and
2. The increments which inclination has undergone from 1780 to 1840 and which appear as differences between the isoclinal maps of the same authors.

The increments of these two phenomena were taken by comparing the said maps for forty-two points of intersection between the meridians of

$$\lambda = 0^\circ,\ 60^\circ,\ 120^\circ,\ 180^\circ,\ 240^\circ,\ \text{and}\ 300^\circ$$

and the parallels of

$$u = 30^\circ,\ 50^\circ,\ 70^\circ,\ 90^\circ,\ 110^\circ,\ 130^\circ\ \text{and}\ 150^\circ;$$

and then, if σ and ι respectively designate the fifty-six years' increment of declination and the sixty years' increment of inclination, and

$$\alpha_1,\ \alpha_2,\ \alpha_3,\ \alpha_4,\ \alpha_5,\ \alpha_6,\ \alpha_7\ \text{and}\ \alpha_8$$

respectively the sought-for annual increments of the Gaussian constants

$$g^{1\cdot 0},\ g^{1\cdot 1},\ h^{1\cdot 1},\ g^{2\cdot 0},\ g^{2\cdot 1},\ h^{2\cdot 1},\ g^{2\cdot 2},\ \text{and}\ h^{2\cdot 2},$$

there were formed forty-two conditional or primary equations to schedule (1), and then just as many to schedule (2).

(1) ...... With ω for the *horizontal intensity*, d for the *declination*, and $\kappa = \frac{56}{\omega \,.\, \sin 1^\circ}$, there had to be calculated for the σ measured by degrees of arc:—

$$a = -\sin u \,.\, \sin d,$$

$$b = +\cos u \,.\, \cos \lambda \,.\, \sin d + \sin \lambda \,.\, \cos d,$$

$$c = +\cos u \,.\, \sin \lambda \,.\, \sin d - \cos \lambda \,.\, \cos d,$$

$$d = -\sin 2u \,.\, \sin d,$$

$$e = +\cos 2u \,.\, \cos \lambda \,.\, \sin d + \cos u \,.\, \sin \lambda \,.\, \cos d,$$

$$f = +\cos 2u \,.\, \sin \lambda \,.\, \sin d - \cos u \,.\, \cos \lambda \,.\, \cos d,$$

$$g = +\sin 2u \,.\, \cos 2\lambda \,.\, \sin d + 2 \,.\, \sin u \,.\, \sin 2\lambda \,.\, \cos d,$$

$$h = +\sin 2u \,.\, \sin 2\lambda \,.\, \sin d - 2 \,.\, \sin u \,.\, \cos 2\lambda \,.\, \cos d,$$

and then formed as primary equations, to which the sought-for $\alpha_1 \ldots \alpha_8$ had to answer as nearly as possible,

$$n = \frac{\sigma}{\kappa} = a.\alpha_1 + b.\alpha_2 + c.\alpha_3 + d.\alpha_4 + e.\alpha_5 + f.\alpha_6 + g.\alpha_7 + h.\alpha_8.$$

(2) ...... The ι or sixty years' inclination-increments being measured by degrees of arc, with i for the *inclination*, $\kappa_\iota = \frac{60}{\omega \,.\, \sin 1^\circ}$, there had to be evaluated:—

$$a = -\sin u \,.\, \sin i \,.\, \cos i \,.\, \cos d + 2 \cos u \,.\, \cos^2 i,$$

$$b = (\cos u \,.\, \cos d \,.\, \cos \lambda - \sin \,.\, d \,.\, \sin \lambda) \,.\, \sin i \,.\, \cos i \\ + 2 \,.\, \sin u \,.\, \cos \lambda \,.\, \cos^2 i,$$

$$c = (\cos u \,.\, \cos d \,.\, \sin \lambda + \sin d \,.\, \cos \lambda) \sin i \,.\, \cos i \\ + 2 \,.\, \sin u \,.\, \sin \lambda \,.\, \cos^2 i,$$

$$d = -\sin \,.\, 2u \,.\, \cos d \,.\, \sin i \,.\, \cos i + (3 \,.\, \cos^2 u - 1) \,.\, \cos^2 i,$$

$$e = (\cos 2u \,.\, \cos \lambda \,.\, \cos d - \cos u \,.\, \sin \lambda \,.\, \sin d) \sin i \,.\, \cos i \\ + \tfrac{3}{2} \,.\, \sin 2u \,.\, \cos \lambda \,.\, \cos^2 i,$$

$$f = (\cos 2u \,.\, \sin \lambda \,.\, \cos d + \cos u \,.\, \cos \lambda \,.\, \sin \lambda) \,.\, \sin i \,.\, \cos i \\ + \tfrac{3}{2} \,.\, \sin 2u \,.\, \sin \lambda \,.\, \cos^2 i,$$

$$g = (\sin 2u \,.\, \cos 2\lambda \,.\, \cos d - 2 \sin u \,.\, \sin 2\lambda \,.\, \sin d) \,.\, \sin i \,.\, \cos i \\ + 3 \,.\, \sin^2 u \,.\, \cos 2\lambda \,.\, \cos^2 i,$$

$$h = (\sin 2u \,.\, \sin 2\lambda \,.\, \cos d + 2 \sin u \,.\, \cos 2\lambda \,.\, \sin d) \,.\, \sin i \,.\, \cos i \\ + 3 \,.\, \sin^2 u \,.\, \sin 2\lambda \,.\, \cos^2 i,$$

and then to be formed as primary equations, to which the $\alpha_1 \ldots \alpha_8$ had to answer as nearly as possible,

$$n = \frac{\iota}{\kappa_1} = a.\alpha_1 + b.\alpha_2 + c.\alpha_3 + d.\alpha_4 + e.\alpha_5 + f.\alpha_6 + g.\alpha_7 + h.\alpha_8.$$

The forty-two numerical values of σ and ι which we have used in the primary equations to the preceding schedules (1) and (2) are shown in the

following Tables. They form the first horizontal line for every value of u, and are marked Ma. when directly made out by the aforesaid maps. We subjoin to them, in the second line for every u, and marked by Ca., the corresponding calculated values, which, according to the solution of our final equations, as has to be shown hereafter, are at once conformable to theory and the closest to the results obtained from the maps.

Values of σ or increments of Declination from 1784 *to* 1840.

u	$\lambda=$	0°.	60°.	120°.	180°.	240°.	300°.
30°	Ma.......	+2·3	−5·4	−1·3	+ 2·2	− 8·7	+ 7·5
	Ca.	−4·11	−8·83	−2·37	+ 1·00	+ 1·35	+14·95
50°	Ma.......	+0·2	−3·9	+1·7	+ 1·0	− 2·7	+ 4·5
	Ca.	−0·02	−4·70	−0·75	+ 0·27	+ 0·60	+ 9·40
70°	Ma.......	+1·3	−3·8	+0·5	+ 1·0	− 3·2	+ 2·2
	Ca.	−0·74	−4·31	+1·04	+ 2·17	+ 0·19	+ 2·95
90°	Ma.......	+4·4	−4·5	−0·9	+ 1·2	− 3·0	+ 0·9
	Ca.	+3·49	−2·08	+0·38	− 1·56	− 1·92	+ 3·01
110°	Ma.......	+6·3	−0·4	+0·2	+ 0·8	− 4·0	+ 3·1
	Ca.	+5·14	+1·08	+0·51	− 2·52	− 2·41	+ 3·21
130°	Ma.	+9·4	−2·4	−4·3	− 0·7	− 7·1	+ 3·5
	Ca.	+3·49	+1·82	+2·26	− 2·02	− 2·80	+ 1·22
150°	Ma.......	+8·6	+6·9	−5·0	− 3·9	−13·3	+ 2·1
	Ca... ...	+6·13	+6·00	+4·37	−10·04	− 4·24	+ 2·93

Values of ι or increments of Inclination from 1780 *to* 1840.

u	$\lambda=$	0°.	60°.	120°.	180°.	240°.	300°.
30°	Ma.......	− 2·0	+0·9	+3·5	+1·4	+2·1	−0·6
	Ca.	− 2·49	−0·03	+2·15	+1·88	+1·71	−1·74
50°	Ma.......	− 2·8	+0·8	+2·0	+2·4	+3·3	+1·6
	Ca.	− 5·37	+0·41	+2·36	+1·38	+4·04	+0·89
70°	Ma.......	−10·8	+2·7	+1·9	+4·6	+8·6	+0·6
	Ca.	− 2·37	− 1·00	+2·27	+1·00	+4·18	+3·04
90°	Ma.......	−13·6	+0·2	0·0	+4·1	+7·5	+3·0
	Ca.	− 4·18	−4·85	+1·37	−0·15	+6·43	+3·61
110°	Ma.......	−13·0	−2·8	−3·7	−0·5	+2·5	+3·2
	Ca.	− 1·37	−3·76	−2·43	−0·24	+7·81	+9·73
130°	Ma.......	− 4·6	0·0	−3·5	−0·9	+4·9	+6·9
	Ca.	− 6·28	−3·86	−4·31	+2·96	+0·80	+1·51
150°	Ma.......	+12·0	+0·5	−1·5	−4·0	+6·0	+7·1
	Ca.	+ 2·0	−0·39	−1·98	−0·40	+3·07	+4·41

The coefficients $a, b \ldots h$ of the primary equations have been calculated with d and i as nearly given for 1811 by a mean between the indications of both isogonic and of both isoclinal maps, and with ω as sufficiently known since 1829.

B. *On the Equations for annual Increments of Constants during the year* 1843·5.

We have already mentioned that our second determination of a set of annual increments $\alpha_1, \alpha_2 \ldots \alpha_8$ of the first eight Gaussian constants was intended to give these quantities for the date 1843·5. This date follows indeed from being the middle of the period 1829–58, during which had happened those changes of phenomena on which we first founded our conditional or primary equations. These were the values of σ or increments of declination that we obtained by a comparison between the normal or theoretically interpolated declinations for 1829, as given in the 'Magnetische Atlas' by Gauss and Weber, and the corresponding ones for 1858, as represented by the isogonic lines in Berghaus's Chart of the World.

These increments result as follows for thirty-six of the before-mentioned points:—

Values of σ or increments of Declination from 1829–58.

λ=	0°.	60°.	120°.	180°.	240°.	300°.
u	°	°	°	°	°	°
30°	−2·2	−4·1	+3·5	−1·6	−4·3	+1·7
50°	−5·7	+0·5	+1·5	−1·8	+0·3	+5·0
70°	−5·1	+1·3	+0·2	−0·3	+2·1	+0·6
90°	+0·1	−0·1	+0·2	+2·0	+2·4	−0·2
110°	+4·4	−3·7	+1·3	−0·7	−0·1	−0·2
130°	+3·9	−1·5	0·0	−2·7	+2·8	−0·4

As no sufficient data exist for a similar collection of the changes which inclination has undergone during the same period, we have completed our material by the following results of researches on secular variation of magnetic elements. If δ generally denotes the *annual* increment of any element *for the date* 1843·5, and f the total magnetic intensity, there were put $X=f \cdot \cos i \cdot \cos d$, $Y=f \cdot \cos i \cdot \sin d$, $Z=f \cdot \sin i$, as well as p for the so-called *weight* or *measure of probability*; and then the following numbers were ascertained, in order to be afterwards combined into conditional equations with the sought-for $\alpha_1, \alpha_2 \ldots \alpha_8$, or annual increments of constants.

Annual Increments of Magnetic Elements for the date 1843·5—*the variations of* X, Y, *and* Z *being measured by units of intensity, the variations of* d *and of* i *by minutes of arc.*

Number of station.	u.	λ.	δX.	δY.	δZ.	p.	The results originating:—
1.	37° 28'·08	13° 23'·20	+0·570	−0·672	−2·710	4	At Berlin.
2.	48 45	352 30·0	+2·996	−0·469	+1·087	3	Out of Erman's observations in Spain and France for 1853·7, and on the Atlantic for 1830.
3.	123 56·05	18 28·50	−1·184	+0·039	−1·277	3	At Cape Town. English observatory.
4.	46 20·4	280 38·5	−0·265	−0·243	+0·165	3	At Toronto. Ibid.
5.	76 56	80 17	+0·856	−0·310	+0·856	3	At Madras. Ibid.
6.	132 52·5	147 27·5	−0·090	−0·261	−0·014	3	At Hobarton. Ibid.
7.	24 46·47	64 39·50	−0·116	−0·681	+1·436	3	At Obdorsk and Beresowsk. Observations for 1828 and for 1849.
8.	133 21·4	225 30·7	+1·002	−3·149	−6·604	1	On the Pacific. Out of observations in 1830 by Erman, and in 1843 on English ships.
9.	132 6·8	308 18·9	+8·069	+0·693	−5·796	1	Ibidem.
10.	141 32·1	254 31·0	+3·105	−6·630	−5·994	1	Ibidem.
11.	143 55·0	302 10·7	+7·415	−0·065	−5·763	1	Ibidem.
12.	147 1·6	283 56·3	+4·140	−7·212	−6·649	1	Ibidem.
13.	105 55·43	354 16·01	δd (+2'·347)	δi (−4'·118)	......	2	At St. Helena. English observatory. Intensity-changes not observed.

The quantity p being supposed to express the number of direct observations which might have given a result of equal accuracy to that in question, it ought to be inversely proportional to the square of the probable error of this result, which latter, in its turn, is unknown. Therefore our suppositions on these values of p could pretend to no more than an approximation to reality, and were then founded partly on regard to the exactitude and completeness of the absolute measurements at different places, partly as follows from some regard to the dates of these performances. Out of the preceding values of annual increments, only those under 1 and 3 have been derived immediately and exclusively from observations at the places named in the same lines; and then, especially if the date is generally marked by $1800+t$, the numerical absolute values of magnetic elements are expressed for *Berlin*, or with u and λ as under 1, according to Erman's observations, by

$$d=18^\circ\ 7'{\cdot}55-0'{\cdot}0700362\,.\,(t-1{\cdot}914)^2,$$
$$i=66\ 37{\cdot}20+0{\cdot}02125\,.\,(t-102{\cdot}2)^2,$$
$$\omega=502{\cdot}04+0{\cdot}0068043\,.\,(t-16{\cdot}108)^2;$$

and for *Cape Town*, or the position as under 3, according to what we have derived from all local English observatory journals, by

$$d = 29^{\circ}\ 33'{\cdot}85 - 0'{\cdot}11273\ (t-58{\cdot}04)^2,$$
$$i = -58\ \ 51{\cdot}07 + 0{\cdot}02242\ (t-165{\cdot}58)^2,$$
$$\omega = 588{\cdot}95 + 0{\cdot}02813\ (t-61{\cdot}806)^2.$$

Now by developing out of each of these expressions, with $t=43{\cdot}5$, their absolute values as well as the annual increments δd, δi, and $\delta\omega$ of the same, and then introducing these quantities into the easily proved expressions,

$$\delta X = \cos d\ .\ \delta\omega - \omega\ .\ \sin 1'\ .\ \sin d\ .\ \delta d,$$
$$\delta Y = \sin d\ .\ \delta\omega + \omega\ .\ \sin 1'\ .\ \cos d\ .\ \delta d,$$
$$\delta Z = \tan i\ .\ \delta\omega + \omega\ .\ \sin 1'\ .\ \sec^2 i\ .\ \delta i,$$

these increments of rectangular components for 1843·5 are obtained as above under 1 and 3.

But for all the other above-named places, the existing observations, when treated as the last mentioned, did not give complete expressions for d, i, and ω, but only their expressions for limited periods. The annual increments of the components X, Y, Z, which were determined from such observations, in general did not exactly pertain to 1843·5, but to a value of t somewhat different from 43·5. Now, as our computation for the first epoch, or 1811, had already furnished the increments of the constants $\alpha_1, \alpha_2 \ldots . \alpha_3$ for the same, we have, first, calculated (by the help of the following formulæ (3), (4), and (5)) the annual increments of X, Y, Z at the same places for 1811, and then, having denoted the value of any one of these increments for

1843·5 by δ,
1811 by δ_{11},
$1800+t$ by δ_t,

we have determined the results, as given above under number 2 and numbers 4 to 13, by the relation

$$\delta = \delta_t + \frac{\delta_t - \delta_{11}}{t-11}\ .\ (43{\cdot}5 - t).$$

There were, in particular, to be used for the increments under numbers

2, $t=41{\cdot}4$,
4, $t=35$,
5 and 6, $t=48{\cdot}5$,
7, $t=38{\cdot}5$,
12, $t=36$,
13, $t=45$;

whereby it appears that the empirical elements of our equations were influenced, to an always slight but not wholly equal extent, by a former calcula-

tion. The values attributed to p had therefore to be assumed with at least an additional regard to this circumstance.

Now, as for the conditional equations themselves, between $\alpha_1, \alpha_2 \ldots \alpha_8$ for 1843·5, and the empiric data hitherto recorded for the same year or for the period 1829–58, it appears, first, that these equations for the "σ or increments of declination from 1829–58" had once more to be formed according to schedule (1) (of A, or "equations for 1811"). In this schedule we had again to make $n=\frac{\sigma}{\kappa}$, but this time with $\kappa=\frac{29}{\omega \,.\, \sin 1^\circ}$.

As for the two values δd and δi that are recorded under number 13, we have employed for δd the said schedule (1), and in it have taken $n=\frac{\delta d}{\kappa}$ with $\kappa=\frac{1}{\omega \,.\, \sin 1'}$, and for δi the schedule (2) (of A, or "equations for 1811"), after substitution of $n=\frac{\delta i}{\kappa}$ with $\kappa=\frac{1}{\omega \,.\, \sin 1'}$; and then, finally, all the recorded values of δX, δY, and δZ were set in equations, according to the following schedules (3), (4), and (5), which we had derived for the purpose.

$$
(3) \;\ldots \begin{cases}
\text{With} \\
a=+\sin u, \quad d=+\sin 2u, \quad g=-\sin 2u \,.\, \cos 2\lambda, \\
b=-\cos u \,.\, \cos\lambda, \quad e=-\cos 2u \,.\, \cos\lambda, \quad h=-\sin 2u \,.\, \sin 2\lambda, \\
c=-\cos u \,.\, \sin\lambda, \quad f=-\cos 2u \,.\, \sin\lambda, \\
\text{there is} \\
n=\delta X=a \,.\, \alpha_1+b \,.\, \alpha_2+c \,.\, \alpha_3+d \,.\, \alpha_4+e \,.\, \alpha_5+f \,.\, \alpha_6+g \,.\, \alpha_7+h \,.\, \alpha_8;
\end{cases}
$$

$$
(4) \;\ldots \begin{cases}
\text{with} \\
a=0, \quad d=0, \quad g=+2\sin u \,.\, \sin 2\lambda, \\
b=+\sin\lambda, \quad e=+\cos u \,.\, \sin\lambda, \quad h=-2\sin u \,.\, \cos 2\lambda, \\
c=-\cos\lambda, \quad f=-\cos u \,.\, \cos\lambda, \\
\text{is} \\
n=\delta Y=a \,.\, \alpha_1+b \,.\, \alpha_2+c \,.\, \alpha_3+d \,.\, \alpha_4+e \,.\, \alpha_5+f \,.\, \alpha_6+g \,.\, \alpha_7+h \,.\, \alpha_8;
\end{cases}
$$

and then

$$
(5) \;\ldots \begin{cases}
\text{with} \\
a=+2\cos u, \quad d=+(3 \,.\, \cos^2 u-1), \quad g=+3\sin^2 u \,.\, \cos 2\lambda, \\
b=+2\sin u \,.\, \cos\lambda, \quad e=+\tfrac{3}{2} \,.\, \sin 2u \,.\, \cos\lambda, \quad h=+3 \,.\, \sin^2 u \,.\, \sin 2\lambda, \\
c=+2\sin u \sin\lambda, \quad f=+\tfrac{3}{2} \,.\, \sin 2u \,.\, \sin\lambda, \\
\text{there is again} \\
n=\delta Z=a \,.\, \alpha_1+b \,.\, \alpha_2+c \,.\, \alpha_3+d \,.\, \alpha_4+e \,.\, \alpha_5+f \,.\, \alpha_6+g \,.\, \alpha_7+h \,.\, \alpha_8.
\end{cases}
$$

C. *Evaluation of the annual Increments* $\alpha_1, \alpha_2 \ldots \alpha_8$ *of the Gaussian constants* $g^{1\cdot0}$, $g^{1\cdot1}$, $h^{1\cdot1}$, $g^{2\cdot0}$, $g^{2\cdot1}$, $h^{2\cdot1}$, $g^{2\cdot2}$, and $h^{2\cdot2}$ *for both epochs, and Reductions made, by the help of these increments, of magnetic Observations from different dates to* 1829.

The heretofore described means had now supplied us for 1811 with eighty-

four, and for 1843·5 with seventy-four numerically different equations of the form

$$n=a\,.\,\alpha_1+b\,.\,\alpha_2+c\,.\,\alpha_3+d\,.\,\alpha_4+e\,.\,\alpha_5+f\,.\,\alpha_6+g\,.\,\alpha_7+h\,.\,\alpha_8,$$

which directly to satisfy was of course in both cases impossible. But in order to determine those two sets of the eight unknown $\alpha_1, \alpha_2 \ldots \alpha_8$, which according to the rules of probability had to be assumed for the first and for the second of the said years, it was necessary to supply the just mentioned theoretical form of the conditional equations by the practically possible assumption of

$$v=(-n+a\,.\,\alpha_1+b\,.\,\alpha_2+c\,.\,\alpha_3+d\,.\,\alpha_4+e\,.\,\alpha_5+f\,.\,\alpha_6+g\,.\,\alpha_7+h\,.\,\alpha_8)\,.\,\sqrt{p},$$

p and v in this expression being meant to stand for the so-called *weight* of every value of n, and for the *error* to be supposed in it.

If, then, [ ] indicate generally a sum of algebraically similar terms, and if the assumed values of the error v be regarded as functions of the unknown, we shall obtain the most probable values of $\alpha_1, \alpha_2 \ldots \alpha_8$ by the solution of the following eight final equations under (6), which in their turn are but evident consequences of the general principle under ($\odot$)

$$(\odot) \ldots\ldots\ldots \quad [v^2]=\text{minimum}.$$

$$(6)\ldots\ldots\left\{\begin{aligned}
\left[v\,.\,\frac{dv}{d\alpha_1}\right]&=o=-[anp]+[aap]\alpha_1+[abp]\alpha_2+[acp]\alpha_3+[adp]\alpha_4\\
&\qquad+[aep]\alpha_5+[afp]\alpha_6+[agp]\alpha_7+[ahp]\alpha_8.\\
\left[v\,.\,\frac{dv}{d\alpha_2}\right]&=o=-[bnp]+[bap]\alpha_1+[bbp]\alpha_2+[bcp]\alpha_3+[bdp]\alpha_4\\
&\qquad+[bep]\alpha_5+[bfp]\alpha_6+[bgp]\alpha_7+[bhp]\alpha_8.\\
\left[v\,.\,\frac{dv}{d\alpha_3}\right]&=o=-[cnp]+[cap]\alpha_1+[cbp]\alpha_2+[ccp]\alpha_3+[cdp]\alpha_4\\
&\qquad+[cep]\alpha_5+[cfp]\alpha_6+[cgp]\alpha_7+[chp]\alpha_8.\\
\left[v\,.\,\frac{dv}{d\alpha_4}\right]&=o=-[dnp]+[dap]\alpha_1+[dbp]\alpha_2+[dcp]\alpha_3+[ddp]\alpha_4\\
&\qquad+[dep]\alpha_5+[dfp]\alpha_6+[dgp]\alpha_7+[dhp]\alpha_8.\\
\left[v\,.\,\frac{dv}{d\alpha_5}\right]&=o=-[enp]+[eap]\alpha_1+[ebp]\alpha_2+[ecp]\alpha_3+[edp]\alpha_4\\
&\qquad+[eep]\alpha_5+[efp]\alpha_6+[egp]\alpha_7+[ehp]\alpha_8.\\
\left[v\,.\,\frac{dv}{d\alpha_6}\right]&=o=-[fnp]+[fap]\alpha_1+[fbp]\alpha_2+[fcp]\alpha_3+[fdp]\alpha_4\\
&\qquad+[fep]\alpha_5+[ffp]\alpha_6+[fgp]\alpha_7+[fhp]\alpha_8.\\
\left[v\,.\,\frac{dv}{d\alpha_7}\right]&=o=-[gnp]+[gap]\alpha_1+[gbp]\alpha_2+[gcp]\alpha_3+[gdp]\alpha_4\\
&\qquad+[gep]\alpha_5+[gfp]\alpha_6+[ggp]\alpha_7+[ghp]\alpha_8.\\
\left[v\,.\,\frac{dv}{d\alpha_8}\right]&=o=-[hnp]+[hap]\alpha_1+[hbp]\alpha_2+[hcp]\alpha_3+[hdp]\alpha_4\\
&\qquad+[hep]\alpha_5+[hfp]\alpha_6+[hgp]\alpha_7+[hhp]\alpha_8.
\end{aligned}\right.$$

We have here retained the general form of this prescription for calculating $\alpha_1, \alpha_2 \ldots \alpha_8$, though when employed for the year 1811 it became simplified

by the occurrence of $p=1$ in every one of the eighty-four termed sums [ ]; whereas in the computations for 1843·5 we had to substitute in the sums [ ], now unity, now another number for the p's of the seventy-four terms, according to the empirical values for that year, as above mentioned under "B. *On the Equations....for* 1843·5."

Now the numerical values for the final equations (6) have been found to be:—

For the year 1811.

$[aa]=+3{\cdot}970$, $[ab]=-4{\cdot}990$, $[ac]=+10{\cdot}685$, $[ad]=+0{\cdot}235$, $[ae]=+3{\cdot}200$, $[af]=+0{\cdot}109$, $[ag]=-0{\cdot}353$, $[ah]=+4{\cdot}971$, $[an]=-8{\cdot}541$.

$[bb]=+68{\cdot}229$, $[bc]=+3{\cdot}758$, $[bd]=+2{\cdot}881$, $[be]=-0{\cdot}408$, $[bf]=+1{\cdot}906$, $[bg]=-3{\cdot}264$, $[bh]=+5{\cdot}044$, $[bn]=-15{\cdot}069$.

$[cc]=+62{\cdot}186$, $[cd]=-2{\cdot}742$, $[ce]=+2{\cdot}290$, $[cf]=+1{\cdot}954$, $[cg]=-6{\cdot}771$, $[ch]=-11{\cdot}994$, $[cn]=-32{\cdot}370$.

$[dd]=+23{\cdot}994$, $[de]=-0{\cdot}455$, $[df]=-2{\cdot}493$, $[dg]=-3{\cdot}006$, $[dh]=-3{\cdot}110$, $[dn]=-8{\cdot}427$.

$[ee]=+16{\cdot}280$, $[ef]=+0{\cdot}699$, $[eg]=-0{\cdot}414$, $[eh]=+7{\cdot}918$, $[en]=-15{\cdot}486$.

$[ff]=+13{\cdot}402$, $[fg]=-6{\cdot}608$, $[fh]=-1{\cdot}268$, $[fn]=+13{\cdot}745$.

$[gg]=+138{\cdot}801$, $[gh]=+5{\cdot}350$, $[gn]=-44{\cdot}715$.

$[hh]=+134{\cdot}680$, $[hn]=-6{\cdot}073$.

For the year 1843·5.

$[aap]=+67{\cdot}883$, $[abp]=+12{\cdot}989$, $[acp]=+9{\cdot}091$, $[adp]=+8{\cdot}784$, $[aep]=+20{\cdot}978$, $[afp]=+2{\cdot}959$, $[agp]=+0{\cdot}407$, $[ahp]=+8{\cdot}036$, $[anp]=+64{\cdot}265$.

$[bbp]=+75{\cdot}782$, $[bcp]=+2{\cdot}961$, $[bdp]=-3{\cdot}325$, $[bep]=+0{\cdot}198$, $[bfp]=-1{\cdot}578$, $[bgp]=+31{\cdot}818$, $[bhp]=+5{\cdot}062$, $[bnp]=-23{\cdot}362$.

$[ccp]=+71{\cdot}859$, $[cdp]=-3{\cdot}574$, $[cep]=+3{\cdot}691$, $[cfp]=+3{\cdot}067$, $[cgp]=-3{\cdot}337$, $[chp]=+23{\cdot}278$, $[cnp]=+25{\cdot}870$.

$[ddp]=+42{\cdot}260$, $[dep]=+7{\cdot}160$, $[dfp]=+8{\cdot}076$, $[dgp]=+2{\cdot}040$, $[dhp]=-1{\cdot}781$, $[dnp]=-29{\cdot}599$.

$[eep]=+43{\cdot}335$, $[efp]=-0{\cdot}359$, $[egp]=+10{\cdot}268$, $[ehp]=+6{\cdot}543$, $[enp]=-7{\cdot}862$.

$[ffp]=+37{\cdot}446$, $[fgp]=-5{\cdot}698$, $[fhp]=+8{\cdot}145$, $[fnp]=-12{\cdot}456$.

$[ggp]=+154{\cdot}637$, $[ghp]=-5{\cdot}424$, $[gnp]=-59{\cdot}602$.

$[hhp]=+122{\cdot}981$, $[hnp]=-18{\cdot}439$.

The solution of the equations (6), when these groups of numbers were successively substituted, gave then the two sought-for sets of results as follows:—

The increment called	pertains to the constants.	Column of δ_{11}, or values of annual increments for 1811.	Column of $\delta_{43\cdot5}$, or values of annual increments for 1843·5.
α_1	$g^{1\cdot0}$	$-0\cdot916$	$+1\cdot339$
α_2	$g^{1\cdot1}$	$-0\cdot303$	$-0\cdot465$
α_3	$h^{1\cdot1}$	$-0\cdot388$	$+0\cdot280$
α_4	$g^{2\cdot0}$	$-0\cdot301$	$-0\cdot829$
α_5	$g^{2\cdot1}$	$-0\cdot795$	$-0\cdot621$
α_6	$h^{2\cdot1}$	$+0\cdot966$	$-0\cdot290$
α_7	$g^{2\cdot2}$	$-0\cdot314$	$-0\cdot255$
α_8	$h^{2\cdot2}$	$+0\cdot027$	$-0\cdot242$

Now, with the help of this Table, the rule for the reduction of any magnetic element that had been observed in the year $1829+\tau$ (with τ for any positive or negative number) to what it must be stated to have been in 1829, proved to be:—

1. That to the observed value must be *added* the number which heretofore has been uniformly designated by n;
2. That this n has to be calculated

by the schedule (1) (under "A. On the equations" &c.) } when a d or a declination is to be reduced;

by the schedule (2) (under the same) } when an i or an inclination is to be reduced;

by the schedule (3) (under "B. On the equations" &c.) } when X or the northern horizontal component is to be reduced;

by the schedule (4) (under the same) } when Y or the western horizontal component is to be reduced;

by the schedule (5) (under the same). } when Z or the vertical component is to be reduced; and

3. That, independently of the nature of the observed element, when calculating its reduction n, there must be substituted, in the formula employed, for α_ν (with $_\nu$ for the integers successively from 1 to 8), a δ_ν which corresponds to the following expression, when

assuming the numbers marked δ_{11} and $\delta_{43\cdot5}$, under the same superscription out of the νth horizontal line of the Table :—

$$\delta_\nu=\tau\,.\left(\frac{-29\,.\,\delta_{11}-36\,.\,\delta_{43\cdot5}}{65}\right)+\tau\tau\,.\left(\frac{+\delta_{11}-\delta_{43\cdot5}}{65}\right)=\tau\,.\,\mathrm{M}+\tau\tau\,.\,\mathrm{N}^*.$$

To facilitate this evaluation, we used the form $\delta_\nu=\tau\,.\,\mathrm{M}+\tau\tau\,.\,\mathrm{N}$, and the following logarithms according to the superscriptions under which they stand:

When δ_ν is substituted for	It must be formed with log M, as follows	It must be formed with log N, as follows
a_1	9·5237 *n*	8·5403 *n*
a_2	9·5942	7·3963
a_3	8·2504	8·0121 *n*
a_4	9·7735	7·9094
a_5	9·8442	7·4279 *n*
a_6	9·4315 *n*	8·2864
a_7	9·4488	6·9509 *n*
a_8	9·0871	7·6174

As a further illustration of these rules, we give the following example of our reductions. In 1818·5 or for $\tau=-10\cdot5$ were observed

u	λ	X	Y	Z
21° 38′,	306° 10′,	73·96,	171·92,	1609·74;

hence for $\delta_\nu=\mathrm{M}\,.\,\tau+\mathrm{N}\,.\,\tau\tau$ is obtained

log δ_ν, when standing for

log α_1, 9·5036 *n*; log α_2, 0·5854 *n*; log α_3, 0·1365 *n*; log α_4, 0·7271 *n*; log α_5, 0·9794 *n*; log α_6, 0·6963; log α_7, 0·4843 *n*; log α_8, 9·7474 *n*.

log *a*, 9·5667; log *b*, 9·7393 *n*; log *c*, 9·8753; log *d*, 9·8359; log *e*, 9·6332 *n*; log *f*, 9·7694; log *g*, 9·3180; log *h*, 9·8149, in δX, according to schedule (3).

And for

$$\delta\mathrm{X},\ a\alpha_1=-0\cdot12,\ b\alpha_2=+2\cdot12,\ c\alpha_3=-1\cdot03,\ d\alpha_4=-3\cdot65,$$
$$e\alpha_5=+4\cdot10,\ f\alpha_6=+2\cdot92,\ g\alpha_7=-0\cdot63,\ h\alpha_8=-0\cdot36;$$

therefore

$$\delta\mathrm{X}=\lfloor a\alpha_1+b\alpha_2\ldots.+h\alpha_8\rfloor=+3\cdot35;\ \mathrm{X}+\delta\mathrm{X}=77\cdot31=\text{the reduced X}.$$

* It scarcely needs to be observed that the above rule applies verbally to reductions from a year $1800+t_1$ to a year $1800+t$ (t_1 and t standing for any positive or negative numbers whatsoever), if only into $\delta_\nu=\tau\,.\,\mathrm{M}+\tau\tau\,.\,\mathrm{N}$ are introduced

$$\tau=t_1-t,\ \mathrm{M}=\frac{-(87-2t)\,.\,\delta_{11}-(2t-22)\,.\,\delta_{43\cdot5}}{65},\ \text{and}\ \mathrm{N}=\frac{+\delta_{11}-\delta_{43\cdot5}}{65}$$

log a, $-\infty$; log b, 9·9070 n; log c, 9·7710 n; log d, $-\infty$; log e, 9·8753 n; log f, 9·7393 n; log g, 9·8467 n; log h, 9·3498, in δY, according to schedule (4).

And for

δY, $aa_1=0{\cdot}00$, $ba_2=+3{\cdot}13$, $ca_3=+0{\cdot}81$, $da_4=0{\cdot}00$, $ea_5=+7{\cdot}16$, $fa_6=-2{\cdot}72$, $ga_7=+2{\cdot}14$, $ha_8=-0{\cdot}13$;

therefore

$\delta Y=[aa_1+ba_2+\ldots\ldots+h\,.\,a_8]=+10{\cdot}39$; $Y+\delta Y=182{\cdot}31=$the reduced Y.

log a, 0·2693; log b, 9·6387; log c, 0·7747 n; log d, 0·1932; log e, 9·7830; log f, 9·9190 n; log g, 8·9926 n; log h, 9·5895 n, in δZ, according to schedule (5).

And for δZ,

$aa_1=-0{\cdot}59$, $ba_2=-1{\cdot}62$, $ca_3=+8{\cdot}15$, $da_4=-8{\cdot}32$, $ea_5=-5{\cdot}79$, $fa_6=-4{\cdot}12$, $ga_7=+0{\cdot}30$, $ha_8=+0{\cdot}22$;

therefore

$\delta Z=[aa_1+ba_2+\ldots\ldots+ha_8]=-11{\cdot}83$; $Z+\delta Z=1597{\cdot}91=$the reduced Z.

II. *Computation of the twenty-four Gaussian Constants from values observed in or reduced to* 1829.

The numerous applications which we made of these means of reduction, not only have added considerably to the number of empirical data for our intended research, but they have also increased the intrinsic value of the whole stock of such data. Indeed many observed elements which by their reduction to the epoch 1829 became applicable to our purpose, related to points of extensive regions where all knowledge of magnetic phenomena had been hitherto wanting. Such were, for instance, the beautiful series of magnetic measurements which English navigators have executed in the antarctic and North-American glacial oceans, and also many magnetic determinations in the interior of the United States. Therefore the materials now collected must amply suffice for our purpose; but it seemed at first sight as if for its attainment two entirely different ways were left to our option. Further consideration, however, has convinced us that of these ways or modes of operating only the one which we have adopted was admissible; but this consideration, together with the doubt which it settled, merits to be shortly explained here.

According to a first plan of operation, we had to begin by calculating for every newly added magnetic element its excess n over the theoretic value assigned to it by the old approximations for the Gaussian constants—then, having formed for each of these results (with a_1, $a_2 \ldots . a_{21}$ for given functions of u and λ, and $\Delta g^{\nu,\mu}$, $\Delta h^{\nu,\nu}$, every ν and μ respectively varying from 1 to 4 and from 0 to 4, for the corrections of constants) the expression

$$n=a_1\Delta g^{1\cdot0}+a_2\Delta g^{1\cdot1}+a_2\Delta h^{1\cdot1}+\ldots\ldots+a_{21}\Delta h^{4\cdot4},$$

to derive from each of these primary equations its corresponding contributions to the twenty-four final equations for $\Delta g^{1\cdot0}$, $\Delta g^{1\cdot1} \ldots . \Delta h^{4\cdot4}$; and lastly,

having added each of these contributions to the similar one among those equations which H. Petersen has stated to represent all the magnetic elements measured by Erman in 1829*, we had to solve the so completed expressions according to the sought-for corrections, $\Delta g^{1\cdot 0}$, $\Delta g^{1\cdot 1}$, $\Delta h^{1\cdot 1} \ldots \Delta h^{4\cdot 4}$.

On the other hand, instead of such indifferent aggregation of all new material to all the old, we had, according to the second method, to make a proper abstract of each of the two classes of data, and then to derive the sought-for values of constants from equations founded only on these abridged materials.

But as the most probable determination of the Gaussian constants is evidently only obtained by observations at points symmetrically situated all over the earth's surface and being all of equal weight (that is to say, reliable to an equal extent), the beforementioned method proved to be doubly imperfect. Indeed the material for the said former calculation of H. Petersen consisted in 610 magnetic elements, which corresponded to 650 direct observations executed along a line round the earth of 8100 German miles. The three data for the magnetic determination of a point, therefore, were to be found all over this line at an average distance of 37·4 German miles, or of very nearly 2°·5 of the equator, whereas when those points for which magnetic elements had now to be added were counted in their succession on parallels of latitude or on any other lines round the earth, there appeared everywhere a much scantier distribution, which on an average did not exceed a sixth or a seventh of what it was for the former calculation. On immediate addition of the former sums of final equations to the corresponding new sums, the resulting new values of Gaussian constants would therefore have been influenced to an exceedingly larger extent by the magnetic character of one almost linear tract of the earth's surface, than by all its remaining parts. To compensate such vicious preponderance, we might, before adding the two sums, have multiplied each of them by a number inversely proportional to the frequency of its elements. But this proceeding supposed, in order to be right, that all constituent observations were of equal weight, while in our case we must own, on the contrary, that the probable errors of the newly added elements surpassed those of the formerly observed ones in a considerable though rather indefinite proportion. Indeed by separate comparisons of some of the new and of the old observations with others of their respective classes, the new seemed upon the whole in less accordance, partly of course in direct consequence of the manner in which they were made, partly because of their having been reduced to 1829 by a method which, for all our care, was but an approximation to reality.

We have avoided these difficulties by choosing the second of the abovementioned modes of operation and by prosecuting it as follows:—

Out of all stations for which the three rectangular magnetic components, as in 1829, had become known, either by direct observation or by our reductions for secular changes, we selected those which are nearest to ten parallels of latitude between $u=23°$ and $u=165°$, and at the same time to the one or the other of nine equidistant points of every one of these circles. Having then concluded out of the results for these stations the 270 elements that belong to the 90 predetermined points, these latter values were exclusively introduced into the like number of our primary equations, which in

* As published in the Report of the Eighteenth Meeting of the British Association, held in 1848, tables facing p. 98, under "Final Equations for the corrections of the Gaussian constants from 610 magnetic elements."

their turn gave the final equations for the most probable twenty-four values of Gaussian constants.

It appears that by so doing we have given to the data of observation, *first*, the requisite symmetrical repartition over the earth, and then, *secondly*, to all its parts the nearest possible equality of weight. Indeed, when selected as just said, there followed one another quite casually, on each parallel, observations that were instituted in 1829 and those which had been reduced to this year, now from the earlier date of their direct validity, now from the later one. These data became therefore affected by the still remaining defects of reduction to a different extent and in alternate directions, just as by those inevitable errors of observation which the usual formation of final equations supposes to exist in their numerical material.

But then, lastly, as to the reduction of elements from the spots of direct observation to the neighbouring predetermined points, we have avoided its prejudicial influence by always using a merely mechanical interpolation, relating to points which in latitude as well as in longitude differed in alternate directions from those points to which we were to reduce them.

The following Table contains, according to the hitherto used notation of $X=f\cos i\cos d$, $Y=f\cos i\sin d$, and $Z=f\sin i$, those values of 270 magnetic elements for 1829 on which our new values of the Gaussian constants have exclusively been founded. To these fundamental numbers are added under ΔX, ΔY, and ΔZ, their respective excesses on the values which a computation with the old assumed constants assigned to them. These latter numbers show thus to what extent the hitherto existing theory of terrestrial magnetism still wanted correction in different parts of the earth's surface.

It is still worth mentioning that, for the determination of our following normal values of X, Y, and Z, we have employed out of the vicinity of the parallels

to $u=23°$, 39 observed elements,
„ $u=30°$, 63 „ „
„ $u=40°$, 63 „ „
„ $u=50°$, 42 „ „
„ $u=75°$, 27 „ „
„ $u=90°$, 39 „ „
„ $u=105°$, 30 „ „

or altogether 303 direct measurements for 7 parallels with 189 normal values.

As for the remaining three parallels, to $u=130°$, $u=150°$, and $u=165°$, we have directly (though always after reduction to 1829) assumed the 81 elements which General E. Sabine, in his 'Report on Magnetic Observations in the Antarctic Ocean,' assigns to the intersections of these circles with the meridians to $\lambda=40°\nu$, where ν denotes the integers from 0 to 8. He has of course deduced these values from a larger number of observations at neighbouring points; and by assuming this number to be 97 or from 32 to 33 for each parallel, we finally obtain 400 for the number of direct measurements that have been used for the estimation of the following 270 normal values.

NORMAL MAGNETIC ELEMENTS THAT HAVE SERVED FOR THE COMPUTATION OF THE GAUSSIAN CONSTANTS FOR 1829.

I. *Values of* X, *or northern horizontal components, and of* ΔX, *or their excesses above their values according to the former theory.*

u	λ =	0°.	40°.	80°.	120°.	160°.	200°.	240°.	280°.	320°	= λ.	u
23°	X =	304·8	368·1	338·7	332·8	377·15	292·2	118·3	27·9	141·3	= X	23°
	ΔX =	+ 0·8	− 31·0	− 22·3	− 12·6	− 2·35	+ 4·2	− 8·9	− 30·5	− 0·5	= ΔX	
30	X =	355·7	470·9	465·2	478·45	575·95	416·4	243·0	143·6	203·65	= X	30
	ΔX =	− 16·5	− 35·0	− 12·2	+ 13·75	+ 30·05	+ 5·6	+ 8·2	+ 4·4	+ 4·75	= ΔX	
40	X =	456·4	600·7	634·75	663·1	697·0	589·5	444·5	319·4	307·8	= X	40
	ΔX =	− 18·5	− 65·7	− 30·65	+ 16·2	− 21·0	+ 13·0	+ 27·2	+ 20·5	+ 1·5	= ΔX	
50	X =	614·7	773·2	835·0	833·4	733·5	666·9	651·9	570·1	450·2	= X	50
	ΔX =	+ 28·5	− 40·0	− 9·4	+ 18·6	− 71·7	− 46·8	+ 35·8	+ 75·0	+ 5·4	= ΔX	
75	X =	783·90	916·1	1018·15	1033·5	914·4	855·3	964·0	992·95	801·0	= X	75
	ΔX =	− 18·5	− 22·4	− 18·85	− 2·4	− 18·0	− 41·4	− 24·6	+ 58·25	− 1·0	= ΔX	
90	X =	863·75	888·6	971·1	1064·8	1013·75	936·8	984·55	1001·3	878·17	= X	90
	ΔX =	+ 59·55	+ 79·1	+ 29·6	+ 40·9	+ 64·85	− 6·0	− 57·95	− 21·5	− 19·53	= ΔX	
105	X =	739·7	690·0	834·15	980·7	986·4	985·8	952·3	929·2	852·6	= X	105
	ΔX =	+ 18·6	+ 63·9	+ 54·95	+ 32·9	+ 23·5	+ 8·2	− 41·9	− 44·0	− 24·0	= ΔX	
130	X =	584·7	471·2	537·5	594·7	663·5	759·7	798·4	798·4	799·7	= X	130
	ΔX =	− 43·2	− 23·2	− 27·6	− 105·1	− 160·1	− 125·0	− 11·1	+ 7·2	+ 30·4	= ΔX	
150	X =	606·9	418·0	282·2	199·1	297·8	436·8	528·7	603·0	739·0	= X	150
	ΔX =	− 67·1	− 107·2	− 115·3	− 129·9	− 89·5	− 59·0	− 22·4	− 47·5	+ 6·4	= ΔX	
165	X =	544·2	367·2	141·1	22·4	− 6·1	107·5	248·3	432·3	573·8	= X	165
	ΔX =	− 95·5	− 85·7	− 44·4	+ 48·9	+ 56·2	+ 45·5	− 12·8	− 57·1	− 77·8	= ΔX	

II. *Values of* Y, *or western horizontal components, and of* ΔY, *or their excesses above their values according to the former theory.*

u	λ=	0°.	40°.	80°.	120°.	160°.	200°.	240°.	280°.	320°	=λ.	u
23°	Y=	+188·1°	− 6·1°	− 99·1°	− 42·5°	− 80·8°	−182·5°	−119·8°	+ 68·8°	+219·4°	= Y	23°
	ΔY=	+ 27·9	− 22·3	− 36·4	− 22·8	− 19·9	− 26·6	− 5·5	+ 15·5	+ 37·5	=ΔY	
30	Y=	+177·7	+ 14·3	− 78·5	+ 1·9	− 49·2	−197·2	−148·15	+ 36·6	+191·1	= Y	30
	ΔY=	− 7·6	− 9·1	− 8·0	+ 2·8	0·0	− 19·2	− 6·25	− 3·8	0·0	=ΔY	
40	Y=	+204·5	+ 30·55	− 90·45	+ 44·45	− 53·2	−250·2	−179·8	+ 47·4	+196·6	= Y	40
	ΔY=	− 20·9	− 17·35	− 11·15	+ 27·55	− 8·9	− 48·7	− 7·8	+ 32·8	+ 4·1	=ΔY	
50	Y=	+192·0	+ 83·8	− 68·5	+ 26·2	− 63·1	−180·0	−187·8	+ 36·2	+182·2	= Y	50
	ΔY=	− 73·1	0·0	+ 17·0	+ 3·9	− 12·6	+ 31·1	0·0	+ 18·5	0·0	=ΔY	
75	Y=	+330·3	+203·0	− 18·2	− 4·95	− 91·9	−146·5	−102·85	−117·0	−142·7	= Y	75
	ΔY=	+ 3·5	+ 30·6	+ 57·3	− 1·25	+ 9·5	+ 28·3	+ 62·45	− 14·6	− 18·7	=ΔY	
90	Y=	+328·65	+219·50	+ 18·05	− 6·3	−154·25	−140·4	− 74·95	−150·8	+ 77·45	= Y	90
	ΔY=	+ 6·65	+ 11·3	+ 53·95	+ 12·6	− 16·35	− 1·8	+ 59·65	− 6·9	+ 1·75	=ΔY	
105	Y=	+268·7	+204·8	+ 38·6	+ 10·3	−182·3	−143·7	−115·7	−155·9	+ 43·5	= Y	105
	ΔY=	− 20·0	− 29·3	− 0·3	+ 18·5	− 21·8	− 21·8	+ 7·7	+ 23·2	+ 12·0	=ΔY	
130	Y=	+227·4	+283·3	+217·7	+ 62·6	−169·0	−158·3	−147·1	−284·0	− 49·7	= Y	130
	ΔY=	+ 17·0	− 6·1	− 4·4	− 20·1	− 24·1	+ 9·7	+ 48·0	− 38·6	+ 3·5	=ΔY	
150	Y=	+170·3	+329·3	+322·7	+ 72·6	−125·7	−150·7	−198·1	−324·3	−133·0	= Y	150
	ΔY=	− 0·5	− 25·2	− 44·9	−114·6	− 33·9	+ 92·2	+118·1	− 10·0	− 18·1	=ΔY	
165	Y=	+121·7	+274·0	+317·7	+146·5	− 58·2	−162·5	−273·5	−302·9	−123·0	= Y	165
	ΔY=	− 42·4	−120·2	−114·3	−102·3	− 10·3	+124·5	+128·2	+ 58·2	+ 18·3	=ΔY	

III. *Values of Z, or vertical components, and of ΔZ, or their excesses above their values according to the former theory.*

u	λ=	0°.	40°.	80°.	120°.	160°.	200°.	240°.	280°.	320°	=λ.	u
23°	Z=	+1462·9	+1456·3	+1594·6	+1681·2	+1647·75	+1691·75	+1775·31	+1704·2	+1545·6	= Z	23°
	ΔZ=	− 11·3	− 36·0	− 12·5	+ 31·1	+ 35·95	+ 46·95	+ 52·55	0·0	− 35·0	=ΔZ	
30	Z=	+1370·3	+1346·3	+1564·4	+1643·3	+1485·1	+1525·6	+1799·0	+1808·6	+1589·1	= Z	30
	ΔZ=	− 37·6	− 57·5	+ 12·4	+ 47·5	− 34·8	− 52·2	+ 78·9	+ 84·3	+ 21·8	=ΔZ	
40	Z=	+1270·4	+1205·4	+1396·0	+1461·3	+1242·1	+1373·2	+1637·4	+1797·5	+1565·9	= Z	40
	ΔZ=	− 26·0	− 10·3	+ 3·5	− 22·5	− 69·3	− 43·0	− 18·5	+ 82·9	+ 28·5	=ΔZ	
50	Z=	+1090·7	+ 960·5	+1127·5	+1179·0	+ 956·2	+1164·9	+1424·1	+1700·4	+1396·3	= Z	50
	ΔZ=	− 57·1	+ 13·5	0·0	− 9·1	− 79·8	− 25·4	− 74·5	+ 77·0	− 68·7	=ΔZ	
75	Z=	+ 558·7	+ 67·2	+ 192·0	+ 298·3	+ 333·6	+ 541·7	+ 618·6	+ 851·4	+ 904·7	= Z	75
	ΔZ=	+ 7·3	+ 22·2	+ 38·4	+ 8·5	+ 77·0	+ 52·5	− 92·6	− 97·0	− 54·7	=ΔZ	
90	Z=	0·0	− 434·9	− 381·65	− 292·2	− 134·7	+ 44·2	+ 55·0	+ 265·6	+ 444·05	= Z	90
	ΔZ=	− 115·5	+ 4·0	+ 33·55	− 4·6	+ 59·0	− 4·5	− 60·0	− 90·0	− 35·25	=ΔZ	
105	Z=	− 298·6	− 750·25	− 844·75	− 868·2	− 770·6	− 489·9	− 448·68	− 168·2	+ 23·4	= Z	105
	ΔZ=	− 45·5	− 11·15	− 3·75	− 42·2	− 99·8	− 61·6	− 4·28	+ 39·2	+ 21·4	=ΔZ	
130	Z=	− 676·4	−1059·9	−1420·6	−1698·2	−1573·2	−1347·0	−1243·4	− 982·4	− 626·9	= Z	130
	ΔZ=	− 6·4	− 26·9	− 88·7	− 72·5	+ 19·2	+ 18·8	− 7·8	− 55·0	+ 3·1	=ΔZ	
150	Z=	−1063·8	−1306·5	−1611·8	−1935·2	−1913·8	−1791·1	−1744·2	−1501·9	−1146·6	= Z	150
	ΔZ=	+ 21·4	+ 1·5	+ 88·8	+ 133·4	+ 249·7	+ 213·7	+ 4·6	− 91·7	− 18·6	=ΔZ	
165	Z=	−1447·4	−1531·0	−1747·0	−1969·1	−2012·1	−1942·1	−1860·6	−1694·1	−1507·0	= Z	165
	ΔZ=	+ 92·0	+ 143·6	+ 174·5	+ 185·0	+ 233·1	+ 225·7	+ 117·9	+ 54·5	+ 65·3	=ΔZ	

We give now the result of our investigation, viz. the *Gaussian constants for* 1829, as resulting from all observations that we have found or made available for the purpose, and thereby forming the best theoretical representation of terrestrial magnetism which we think can up to the present be effected. The *probable error* that is subjoined to each of these numbers shows to what extent it may be relied upon; but as these valuations are only founded on the differences between the values that were assumed for our 270 normal elements and those which the new constants assign to the same, the mean of their amount may perhaps be still altered by the more numerous comparisons of directly observed and newly calculated elements that will soon be instituted and published.

The Gaussian constants for 1829, *and their probable errors.*

Names.	Values of the constants, in conventional units, of the Gaussian theory*.	Probable errors.
$g^{1\cdot0}$	+916·041	±1·79
$g^{1\cdot1}$	+ 81·144	2·97
$h^{1\cdot1}$	−172·030	2·32
$g^{2\cdot0}$	+ 3·463	2·04
$g^{2\cdot1}$	−127·463	3·92
$h^{2\cdot1}$	+ 2·060	3·08
$g^{2\cdot2}$	+ 3·575	2·61
$h^{2\cdot2}$	− 36·167	1·03
$g^{3\cdot0}$	− 53·699	5·41
$g^{3\cdot1}$	+ 85·466	4·24
$h^{3\cdot1}$	+ 47·069	4·60
$g^{3\cdot2}$	− 87·942	7·44
$h^{3\cdot2}$	− 17·776	1·82
$g^{3\cdot3}$	− 3·640	0·73
$h^{3\cdot3}$	− 20·744	0·58
$g^{4\cdot0}$	− 78·353	4·83
$g^{4\cdot1}$	−109·919	8·63
$h^{4\cdot1}$	− 9·150	6·97
$g^{4\cdot2}$	− 44·624	7·44
$h^{4\cdot2}$	+ 31·054	2·95
$g^{4\cdot3}$	+ 19·198	1·67
$h^{4\cdot3}$	+ 8·627	1·31
$g^{4\cdot4}$	+ 2·561	0·54
$h^{4\cdot4}$	+ 3·173	±0·68

The derivation of the most interesting consequences of these numerical results and a complete comparison of observed magnetic elements with both their representations by the old and by the newly founded theory being deferred for the moment, in the mean time the following shows the effect of our performance for those parallels that were especially considered.

* Each = 0·00349412 German unit of absolute intensity
= 0·0075781 English " " " .

Means of probable errors.

On the parallel to u.	Of the old theoretic evaluation of the X.	Of the new theoretic evaluation of the X.	Of the old theoretic evaluation of the Y.	Of the new theoretic evaluation of the Y.	Of the old theoretic evaluation of the Z.	Of the new theoretic evaluation of the Z.
23°	±11·58	±14·42	±17·28	±12·98	± 29·52	±30·34
30	12·06	18·04	5·67	8·71	35·46	28·32
40	19·71	23·77	16·25	13·93	28·42	28·95
50	29·43	22·56	18·97	15·29	36·77	32·44
75	19·14	21·55	22·02	17·82	40·07	29·00
90	32·43	22·70	18·76	10·12	39·56	34·16
105	26·05	19·06	12·90	16·32	31·61	33·25
130	53·48	25·67	16·46	10·43	34·02	29·06
150	53·88	22·98	44·86	23·05	84·96	30·60
165	±42·38	±21·29	±60·51	±21·49	±105·51	±16·36
On average	±33·45	±21·41	±28·43	±15·98	± 52·54	±29·10

The new elements of theory have therefore lessened the probable errors

	Of the X.	Of the Y.	Of the Z.
On average...	to 0·6412 of their former value.	to 0·5612 of their former value.	to 0·5539 of their former value.
And on the parallel to $u=165°$	to 0·5012 of their former value.	to 0·3552 of their former value.	to 0·1552 of their former value.

Berlin, February 29th, 1872.

Second Supplementary Report on the Extinct Birds of the Mascarene Islands. By ALFRED NEWTON, *M.A., F.R.S.*

THE small portion of the grant so liberally voted by the Association at the Birmingham Meeting in 1865, to aid my brother Mr. Edward Newton in his researches into the extinct birds of the Mascarene Islands, which remained unexpended at the time of my last reporting his progress, has during the last year or so been employed by him in a renewed examination of the caves in the island of Rodriguez, which had already produced so much of interest.

This examination has been conducted, as before, by Mr. George Jenner, lately the chief executive officer of the island; and though I am not in a position to give any thing like a detailed account of the results, I am happy to say that I believe they will be found in time to be fully as instructive as those of the former examination have been. We are now in possession of several parts of the skeleton of *Pezophaps* which have hitherto been wanting, and of more perfect specimens of some of those bones which we before obtained. We have also additional remains of the large Psittacine bird, described from a single fragmentary maxilla by Prof. Alphonse Milne-Edwards as *Psittacus* (?) *rodericanus*; and this, I hope, will enable that accomplished palæontologist to determine more particularly the affinities of the species, which have hitherto been doubtful; and I may add that thus some further light may be thrown upon the position of the *P. mauritianus* of Prof. Owen. In the course of last year my brother had the pleasure of receiving from Mr. Jenner proof of the continued existence of one of the species described by Leguat as inhabiting Rodriguez, but thought to have become extinct. This proof consisted of a specimen procured in spirit of an undescribed and very distinct *Palæornis*, which I have since described (Ibis, 1872, p. 33) as *P. exsul*. Among the bones sent by Mr. Jenner are, I believe, some which belonged to this bird. But more remarkable and interesting still are some remains which are obviously those of a Ralline bird, unquestionably allied to *Ocydromus*; and these M. Alphonse Milne-Edwards informs me he is inclined to refer to the "Gelinotte" mentioned by Leguat, the nature of which has hitherto been only open to guess. There are also bones of other species of birds, perhaps only inferior to this in interest. Most of these specimens have been intrusted to the care of M. Alphonse Milne-Edwards; for my brother and I believe that the distinguished author of the 'Oiseaux Fossiles de la France' has established a claim upon the assistance of all who are interested in extinct ornithology by that admirable work of his; and I learn from him that he will shortly make public the results of these recent discoveries.

Report of the Committee for Superintending the Monthly Reports of the Progress of Chemistry, consisting of Professor A. W. Williamson, *F.R.S.*, Professor Frankland, *F.R.S.*, *and* Professor Roscoe, *F.R.S.*

During the current year the Chemical Society has continued the publication of the monthly reports of the progress of Chemistry, which had been commenced last year with the aid of the British Association. The labour of preparing these Reports is considerable; and it is due to the chemists who perform that arduous duty to acknowledge the great care which is bestowed upon it by them for a remuneration scarcely more than nominal.

It has been found necessary, in view of the very great number of chemical papers, to render the reports very brief, so as to convey a knowledge of the general results of each paper without giving the details of evidence.

The Members of the Committee have had the pleasure of noticing that the reports are considerably valued by English chemists; and there is reason to believe that the anticipations which were formed of their usefulness in promoting the advancement of chemistry will be fully realized.

Report on the best means of providing for a Uniformity of Weights and Measures, with reference to the Interests of Science, by a Committee consisting of Sir JOHN BOWRING, *F.R.S.*, The Right Hon. Sir STAFFORD H. NORTHCOTE, *C.B., M.P.*, The Right Hon. Sir C. B. ADDERLEY, *M.P.*, SAMUEL BROWN, *F.S.S.*, Dr. FARR, *F.R.S.*, FRANK P. FELLOWES, Professor FRANKLAND, *F.R.S.*, JAMES HEYWOOD, *F.R.S.*, Professor LEONE LEVI, *F.S.A., F.S.S.*, C. W. SIEMENS, *F.R.S.*, Professor A. W. WILLIAMSON, *F.R.S.*, Dr. GEORGE GLOVER, Sir JOSEPH WHITWORTH, *Bart., F.R.S.*, J. R. NAPIER, J. V. N. BAZALGETTE, *and* Sir W. FAIRBAIRN, *Bart., F.R.S.*

THE Metric Committee of the British Association have much pleasure in reporting that another great stride has been made towards the attainment of uniformity in the Weights, Measures, and Coins of all countries by the passing of a law in Austria, in June 1871, rendering the use of Metric Weights and Measures permissive from the 1st of January, 1873, and compulsory from the 1st of January, 1876. The Metric System is gradually diffusing itself all over Europe. At this moment fully two thirds of that Continent, measured by population, have adopted the Metric System of Weights and Measures, and the other third has manifested sufficient interest in the question to justify the expectation of its early adhesion to the general agreement: but in this third there are comprised Russia and England, two countries which, by their population and commerce, exercise an enormous influence in the whole world.

The state of the question in Russia appears to be as follows:—In 1859 a Committee of the Imperial Academy of Russia, consisting of the Academicians Ostrogradski, Jacobi, and Kupffer, issued a report on the subject, which approved of the decimal division already incorporated in the Russian System, the rouble being divided into 100 kopecks, the vedro into 10 krouchki, and the inch into 10 lines, and expressed an opinion in favour of extending such decimal divisions to Weights and Measures. In discussing, however, the possibility of even this moderate reform, the Academicians saw that a very considerable change would be required. Supposing the foot were retained as a unit, how could it be decimalized without abandoning altogether such divisions as the archine, which is $2\frac{1}{3}$, and the sagene, which is 7 feet? Yet these are really more in use than the foot itself. And what multiples could be adopted? The foot of Russia, which is identical with that of England, is too small to measure cloth by, and 10 feet would be too large a unit. With such difficulties attending the decimalization of the existing Weights and Measures, the Academicians felt that it would be far better for Russia at once to introduce the Metric System; and this was the conclusion of their recommendations. Since the publication of this Report, the Imperial Academy of Russia has taken an active part in the advance of the system all over the world. In 1867 M. Jacobi was a Member of the International Committee on Weights, Measures, and Coins in connexion with the Paris International Exhibition, and wrote the report which was agreed to by the representatives of all the nations who took part in the Conference on the subject. And later still, in 1870, on the representation of the Imperial Academy of Russia to the French Government and to the scientific bodies of other nations of the need of preparing more accurate and uniform Metric Standards for the use of countries which might adopt the Metric System, an International Commission was appointed to prepare such Standards. This Commission met in Paris in June 1870, and is about to resume its labours

in September next. These steps on the part of the Imperial Academy of Russia have not been followed by legislative action; yet, when we consider the just influence which the Academy exercises in a subject of this nature, it is reasonable to anticipate that their recommendations will be duly heeded, and that as soon as the Standards are completed the Russian Government will take into consideration the necessary steps for introducing the Metric System, whereby the Weights and Measures of Russia may be rendered identical with those of the greater number of European nations.

In the United Kingdom considerable progress has been made towards the introduction of the Metric System, though much certainly remains to be done. In 1862 a Committee of the House of Commons was appointed to consider the practicability of adopting a simple and uniform system of Weights and Measures, with a view not only to the benefit of our internal trade, but to facilitate our trade and intercourse with foreign countries. In discussing the question of the possible decimalization of the existing system, the Committee of the British House of Commons, in the same manner as the Committee of the Imperial Academy of Russia, reported that it would involve almost as much difficulty to create a special decimal system of our own as simply to adopt the Metric Decimal System in common with other nations; and under these circumstances the Committee came to a unanimous recommendation in favour of the introduction of the Metric System.

Accordingly in 1864 an Act was passed to render permissive the use of such Weights and Measures so far as to legalize contracts made in terms of Metric Weights and Measures, which were heretofore prohibited; but no provision having been made for obtaining correct Standards whereby to verify the same, the use of the System in shops was not thereby permitted. A Royal Commission has, however, inquired into the question on the Metric Weights and Measures of the United Kingdom; and after considerable inquiry it issued a report recommending the preparation of such Standards and the removal of every difficulty which may yet exist in the way of the permissive use of Metric Weights and Measures. We may therefore hope that Her Majesty's Government will speedily bring forward a measure for carrying the recommendation of the Commissioners into effect.

The appended map of Europe (Plate I.) shows how extensively the Metric System is already used. If once Russia and England should finally place their legislation on the same footing, other States will certainly follow, and in Europe, at least, we shall have attained perfect unity as regards Weights and Measures. But in other parts of the world also considerable progress has been made. In Asia the whole of India may be said to have adopted the Weights and Measures of capacity of the Metric System, though some time may elapse before the Act passed by the Indian Government can be carried into operation. In America the United States have introduced it permissively, whilst Brazil, Chili, Mexico, New Granada, and other American republics have adopted the Metric System absolutely. Throughout the world as many as 213,000,000 of people have adopted it absolutely, 160,000,000 more partially, and 70,000,000 permissively, giving a total of 443,000,000.

Nor has there been less done as regards the coinage. If we compare the coins now in use all over the world with those in use some twenty years ago, it will be seen what advance we have already made everywhere towards unity. Some countries, such as France, Italy, Switzerland, Belgium, Greece, and Roumania, have already an identical system of coinage secured to them by the Coinage Convention of the 23rd of December, 1865. The Austro-Hungarian Empire issues gold pieces marked 20 florins and 8 florins, equal to

25 francs and 10 francs respectively. Spain issues gold pieces of 25 pecetas, equal to the 25-franc pieces; and Sweden the caroline, equal to 10 francs.

The Committee much regret that the German Empire, which had recently a most favourable opportunity for extending the desired uniformity (an object to which she has shown her adherence by the recent adoption of the Metric System), has issued a new gold coinage having nothing in common either with the money of the Convention of France, Switzerland, Italy, Belgium, or with the monetary systems of England or the United States. It is much to be desired that we should clearly understand the points on which a common accord exists in matters of international coinage. There is a general agreement on the advantage of a complete decimal system, on the adoption of the fineness at nine tenths fine and one tenth alloy; and the greatest number of States agree also on the adoption of gold as the only standard of value. Between the three leading systems of the world, founded respectively on the Franc, the Dollar, and the Pound Sterling, a point of contact has been found in the 5-franc piece and its multiples, the 5, 10, 20, and 25-franc pieces; and considerable agreement has already been obtained in this method of approaching the question. Your Committee would look forward to a much greater identity of coinage being ultimately realized than would be obtained by this method; but it should be remembered that even the universal acceptance of this plan would immensely simplify the relations of coinage between the different nations, and of necessity lead to a more identical system.

During last year your Committee have had communications with the Indian Government on the question of introducing the Metric System of Weights and Measures in India, the original Act by which all the Weights and Measures of the System were introduced having been vetoed by the Home Government, and another, limited to Weights and Measures of capacity, having been passed in its stead. In England the action of the Committee has been most influential, especially in connexion with education. It was at the instance of this Committee that the Committee of Her Majesty's Privy Council on Education have inserted in the Code a clause requiring that instruction on the Metric Weights and Measures shall be given in the Elementary Schools in the Kingdom. And in order to stimulate education on the subject, to explain the general character of the Metric System and its relation to the Imperial, and to indicate the advantages which would result from an International System of Weights and Measures, your Committee have granted to the British and Foreign Schools, the National Schools, the Wesleyan Schools, and the Congregational Schools in England, as well as to the National Schools in Ireland, copies of Books and Diagrams on the Metric System, which have been gratefully received. The Committee were anxious to purchase a set of Metric Standards, as stated in their last Report, for the purpose of illustrating lectures and papers on the subject; but they found that while their cost would have absorbed nearly the whole vote, it would have been impossible to lend out such standards without endangering their preservation.

In January 1872 a public meeting was held at the Mansion House, under the presidency of Sir John Bennett, Sheriff of London, when resolutions were passed in favour of the early introduction of the Metric System of Weights and Measures and the Decimal Division generally. At this meeting Sir John Lubbock, F.R.S., General Strachey, of the India House, the Rev. William Jowitt, Dr. Farr, F.R.S., the Hon. N. G. Northope, Superintendent of Public Instruction in the United States, the Hon. Mr. Ryan, of the Canadian Senate, and other persons of distinction took part.

The unification of the Weights, Measures, and Coins all over the world is

fraught with immense benefit to science, commerce, and civilization, and philosophical and scientific bodies of all nations have given their adhesion to it; the commercial classes look to such unification as an essential element in the economy of time and the performance of international works, and travellers all over the world regard it as the greatest boon that could be conferred. Towards the attainment of this important object, the Metric Committee of the British Association for the Advancement of Science have exercised an important influence; and they trust that if they are allowed to continue their action for a few years longer, they will be able to report the recognition all over the world of the principle for the promotion of which they were appointed.

In conclusion, your Committee recommend their reappointment.

Eighth Report of the Committee for Exploring Kent's Cavern, Devonshire, the Committee consisting of Sir CHARLES LYELL, *Bart., F.R.S.*, Professor PHILLIPS, *F.R.S.*, Sir JOHN LUBBOCK, *Bart., F.R.S.*, JOHN EVANS, *F.R.S.*, EDWARD VIVIAN, *M.A.*, GEORGE BUSK, *F.R.S.*, WILLIAM BOYD DAWKINS, *F.R.S.*, WILLIAM AYSHFORD SANFORD, *F.G.S., and* WILLIAM PENGELLY, *F.R.S.* (*Reporter*).

IN commencing this, their Eighth Report, the Committee have to state that since their last Report was sent in (Edinburgh, 1871) the excavations have been carried on by the same workmen, without interruption, and in all respects in the same manner as in former years.

The visitors to the Cavern have continued to be very numerous. Amongst those accompanied by the Superintendents, the following may be mentioned:—The Emperor Napoleon III., the Prince Murat, the Prince and Princess of Oldenberg, Sir W. Jardine, Bart., Sir W. Topham, Rev. M. Brown, Rev. G. Buckle, Rev. Mr. Drewe, Rev. Dr. MacGregor, Rev. F. A. Saville, Rev. W. Thompson, Rev. H. H. Winwood, A. D. W. R. B. Cochrane, M.P., W. H. Smith, M.P., General Freeze, C.B., R.A., Colonel Naylor, Colonel W. Pinney, Captain S. P. Oliver, R.A., Professor F. Roemer, of Breslau, Professor A. Newton, Dr. Bond, Dr. Hounsell, Dr. Schmidt, of Essen, Rhenish Prussia, and Messrs. Bosanquet, H. H. Bothamley, W. R. A. Boyle, — Chaplin, B. J. M. Donne, W. Fenner, R. Gwatkin, J. Holdsworth, J. H. Parsons, E. C. Robson, — Stewart, J. Stilwell, G. C. Swayne, E. B. Tawney, B. Tower, — Waldegrave, W. Vicary, I. Whitwell, and A. W. Wills. The Cavern has also been visited by the Exeter Naturalists' Club, and by a large party of Members of the British Medical Association, at the close of the Annual Meeting at Plymouth in August 1871, including Rev. Professor Haughton, Professor Lister, Dr. Crossby, of Nice, Dr. A. Godson, Dr. Lang, Dr. Macnamara, Dr. Murphy, Dr. W. Roberts, and Mr. Wilde.

Visitors of a much less welcome character have also been numerous during the year. In February last the workmen somewhat frequently observed several large rats running about the Cavern, but for some time failed in all their efforts to capture them. One morning one of the men, on commencing his work, wrapped his dinner-bag in the coat he had just taken off, and put the whole carefully aside. At dinner-time the coat was found to be eaten through, and the bag with its contents was gone. A few days after, the other man, having taken his dinner, placed his bag, containing a piece of bread, in a basket, and fastened the cover. On leaving work, he found a hole had been

eaten through the basket, the bag was torn into the merest shreds, and the bread was gone. Thus stimulated, the men baited their traps with great care, and had the pleasure of catching seven or eight rats. No further annoyance was experienced until July, when a large rat was seen to enter the Cavern about midday. The poor wretch was found dead in the trap in a day or two.

During the last twelve months the Committee have explored the branches of the "Western Division" of the Cavern known as "The Wolf's Cave," "The Cave of Rodentia," and "The Charcoal Cave," and have commenced "The Long Arcade."

The Wolf's Cave.—That branch of the Cavern which extends in a northerly direction from "The Sloping Chamber" was, by Mr. MacEnery, termed "The Wolf's Cave," and occasionally "The Idol Cave"*. It received the latter name from "a column of spar" which, "near its entrance, joined the ceiling and floor and obstructed the way," and "had a singular resemblance to a Hindoo Idol"†; and the former, because, on the removal of this "column," it was found to have "covered the head of a wolf, perhaps the largest and finest skull, whether fossil or modern, of that animal in the world"‡.

Mr. MacEnery seems to have been eminently successful in collecting specimens in this branch of the Cavern; for he states that "of the quantity and condition of the remains here it is scarcely possible to give a just idea without appearing to exaggerate. They were so thickly packed together that, to avoid injuring them, we were obliged to lay aside the picks and to grub them out with our fingers. They were found driven into the interstices of the opposite wall, or piled in the greatest confusion against its sides, with but a scanty covering of soil, and that of the finest and softest sand intermixed with greasy earth. To enumerate the amount of fossils collected from this spot would be to give the inventory of half my collection, comprising all the genera and their species, including the *cultridens*. There were hoards." Here, too, he appears to have found all the remains of *Machairodus latidens* (known then as *Ursus cultridens*) the Cavern yielded him, which he states were five canines and one incisor§.

When completely excavated to the depth of 4 feet below the base of the Stalagmitic Floor, this Cave was found to extend nearly 70 feet in a north-westerly direction, and at its entrance, or junction with the Sloping Chamber, to be about 40 feet wide. At 3 yards inside the entrance it narrows to about 20 feet, at 7 yards to 10 feet, and beyond this its general width is from 7 to 8 feet‖. Its present height is about 7 feet throughout; but before the commencement of Mr. MacEnery's diggings, the space between the Limestone Roof and the Stalagmitic Floor could nowhere have exceeded 2 feet, even if the latter had been entirely free from rubbish. Indeed he states that when they first entered this branch, he and his companions "crawled like tortoises"¶.

At the entrance the Roof is commonly fretted as if by the action of acidulated water; but here and there, and especially on the eastern side, its comparatively fresh and smooth aspect indicates what may be termed the *recent* fall of masses of limestone from it,—an indication confirmed by the presence of such masses, some of them of great dimensions, immediately below. At intervals throughout the entire length of the Cave transverse lines of fracture, or divisional planes, appear in the Roof: some of them are close-fitting,

* He also spoke of it sometimes as "The Wolf's Passage" and "The Wolf's Grave."

† See Tr. Devon. Assoc. vol. iii. pp. 243, 293 (1869). ‡ Ib. p. 243. § Ib. pp. 369, 370.

‖ The breadth is always measured at the level of the surface of the Cave-earth. In this Cave it was invariably narrower at the bottom of the excavation.

¶ See Trans. Devon. Assoc. vol. iii. p. 292.

but occasionally they have been corroded or fretted into cavities of rudely elliptical outline, from a foot to 2 feet in height. The largest of them measures 5 feet long and something less than 1 foot wide; its walls are much fretted, and numerous pipe-like stalactites depend from its roof. Some of the holes are completely lined with stalactite, whilst others are quite bare. There are no traces of Cave-earth in any of them.

The north-eastern wall of the Cave, from the entrance to nearly 30 feet within it, is a confused mass of large fallen blocks of limestone. With this exception, the walls, as in the other branches of the Cavern, consist of beds of limestone *in situ*. They are not much fretted, their edges are all more or less angular, and they are here and there traversed by fissures corresponding with the lines of fracture in the Roof.

From the considerable remnants left undisturbed by Mr. MacEnery, there was, no doubt, a continuous "Granular Stalagmitic Floor" from end to end. It seems to have varied from 3 to 12 inches in thickness, and to have possessed the granular and laminated structure characteristic of the Floor covering the "Cave-earth." In a large area at the south-eastern angle of the Cave the Floor had been left untouched, and was found to be in some cases fully 2 feet thick. Like that in a great part of the adjacent Sloping Chamber, of which it is a prolongation, it contained numerous large masses of limestone and of the "Old Crystalline Stalagmitic Floor" so frequently mentioned in former Reports.

Similar masses, of both kinds, were abundant in the Cave-earth below the Floor in the area just mentioned; and in some instances the blocks of limestone lay across one another with but little deposit between them, as if they had fallen after the accumulation of Cave-earth had ceased. In a few instances the cavities or interspaces were not covered with the Stalagmite, and some of them contained a few recent bones and other objects.

Omitting this south-eastern area, Mr. MacEnery extended his researches quite to the innermost point of the Cave, and, with few exceptions, up to 13 feet from the entrance, had broken up and searched the entire deposit to a depth exceeding the Committee's four-feet sections. Within the point just specified, he contented himself with cutting a comparatively narrow trench, leaving the ground quite intact adjacent to, and a few feet from, the south-western wall, but, as before, carrying his excavations to a depth exceeding 4 feet. At 24 feet from the entrance, however, he dug to no greater depth than 2 feet, and very rarely exceeded this in the inner part of the Cave,—thus leaving the Committee's third and fourth foot-levels everywhere intact, besides the belt adjacent to the south-western wall, of which, as already mentioned, no portion was touched. This margin, it may be presumed, was left intact in consequence of all the excavated material being lodged on it. No portion of the latter appears to have been taken out of the Cave.

The deposit the Committee found in the Wolf's Cave, whether disturbed or undisturbed, was well-marked typical Cave-earth, consisting of red loam with about 50 per cent. of angular fragments of limestone. There were no traces of the older deposit termed "Breccia" in previous Reports, either *in situ* or redeposited, and, excepting the area in the south-eastern corner, already mentioned, no fragments of the Old Crystalline Stalagmitic Floor.

In proceeding to the objects found in the Wolf's Cave, it is obvious that nothing can be said about such as may have been on or in the Stalagmitic Floor; they, if such there were, had no doubt been secured by the earlier explorers.

It has already been stated that there were occasional interspaces among

the blocks of limestone lying confusedly in the south-eastern portion of the Cave. In some of these, all of them being sealed up with Stalagmite, shells of the common Pecten (*Pecten maximus*, Linn.) were found, amounting to a total of twenty-five. Most of them were large shells, and some were thickly incrusted with calcareous matter containing, in one or two cases, traces of charred wood. In one instance two, and in another five, shells were found fitted neatly into one another, and cemented together with carbonate of lime, thus leaving no doubt that man had not only packed them, but placed them where they were found. The fact that some of them were "dead shells," having Serpulæ attached to their inner surfaces, indicates, of course, that they were not in all cases taken to the Cavern because they contained an article of food, but probably sometimes, at least, as domestic vessels.

The undisturbed Cave-earth in this branch of the Cavern yielded a considerable number of the remains of the ordinary Cave-mammals, including nearly sixty shells, which may be distributed as in the following Table:—

TABLE I.—Showing how many per cent. of the Teeth found in Cave-earth in the Wolf's Cave belonged to the different kinds of Mammals.

Hyæna..........	44·5 per cent.	Elephant........	2·5 per cent.
Horse..........	25 ,,	Lion..........	1 ,,
Rhinoceros......	15 ,,	Wolf..........	1 ,,
Megaceros......	3 ,,	Ox............	1 ,,
Bear...........	3 ,,	Rabbit..........	·5 ,,
Deer...........	2·5 ,,	Fox............	only 1 tooth.

It will be remembered that the Cave-earth is excavated in vertical slices or "Parallels" extending generally from wall to wall of the branch of the Cavern under exploration, to a depth of 4 feet and a horizontal thickness of 1 foot; that each Parallel is taken out in 4 successive "Levels," each a foot in vertical depth; and each Level in "Yards," or masses 3 feet in length.

From what has been already stated, it is obvious that in the Wolf's Cave there were no continuous first or second Foot-levels intact, and that even the third and fourth were not everywhere met with. Confining attention to the twenty-one instances of each of the two latter which did occur in the same Parallels, the following Table will show the distribution of the teeth of the various kinds of Mammals in them:—

TABLE II.—Showing the distribution of the Teeth of the different kinds of Mammals in the third and fourth Foot-levels of twenty-one Parallels of Cave-earth in the Wolf's Cave.

	Hyæna.	Horse.	Rhinoceros.	Megaceros.	Bear.	Elephant.	Wolf.	Lion.	Deer.	Ox.
No. of Parallels containing teeth in 3rd Level...	16	12	9	2	4	4	0	2	0	1
,, ,, ,, 4th ,, ...	16	14	15	2	2	2	1	2	1	1
,, ,, ,, both Levels	19	18	18	3	6	6	1	4	1	1
Total No. of teeth in 3rd Level....................	63	24	11	13	4	4	0	2	2	1
,, ,, 4th ,, ...	68	29	21	3	2	2	5	2	0	1
,, ,, both Levels................	131	53	32	16	6	6	5	4	2	2

The following examples will serve to explain Table II.:—Teeth of hyæna occurred in the third Foot-level in 16 distinct Parallels, and in the same number in the fourth; but as they were met with in a total number of 19 Parallels only, it is obvious that in 13 instances $(=16+16-19)$ they occurred in both levels in the same Parallel.

Again, as the Table comprehends 21 Parallels, and teeth of hyæna were found in 19 only, it follows that there were 2 Parallels $(=21-19)$ in which no teeth of this genus presented themselves.

Further, a total of 131 teeth of hyæna were exhumed in the 19 Parallels, and of these 63 were in the third Foot-level, and 68 in the fourth or lowest; hence the different Levels were almost equally rich, and on the average several teeth occurred in one and the same Level and Parallel.

To take another example:—Teeth of bear were found in the third Foot-level in 4 Parallels, and in the fourth Foot-level in 2; but as they occurred in a total number of 6 Parallels, it is obvious that in no instance were they met with in both Levels in one and the same Parallel $(4+2-6=0)$.

Again, as the Table comprehends 21 Parallels, and teeth of bear were found in 6 only, it follows that there were 15 Parallels $(21-6=15)$ in which no teeth of this genus presented themselves.

Further, a total of 6 teeth of bear were exhumed in the 6 Parallels, and of these 4 were in the third Level and 2 in the fourth or lowest; hence the third was the richest Level, if the slender evidence may be trusted; and the teeth occurred singly, no more than one having in any instance been found in the same Parallel.

It is perhaps noteworthy that whilst teeth of rabbit and fox occurred in the Wolf's Cave, as is shown in Table I., they did not, according to Table II., present themselves in either the third or fourth Level.

As in previous years, the Committee have removed and examined the deposits dug up and thrown aside by Mr. MacEnery. In the Wolf's Cave, as elsewhere, this material yielded a large number of the remains of the ordinary Cave-mammals, including about 350 teeth, which may be thus apportioned:—

Table III.—Showing how many per cent. of the Teeth found in the disturbed material in the Wolf's Cave belonged to the different kinds of Mammals.

Hyæna	36 per cent.	Bear	1·5 per cent.
Horse	33·5 "	Deer	1·5 "
Rhinoceros	19 "	Badger	1·5 "
Megaceros	3 "	Ox	less than 1 per cent.
Sheep	2 "	Lion	" "

Though it would be utterly useless to compare Tables I. and III., since the latter includes teeth not only from all Levels, but possibly such as were lying *on* the Stalagmitic Floor, as well, perhaps, as more recent introductions, it is not without interest to observe that even amongst the rejected or neglected specimens, as the case may be, as well as in the undisturbed Cave-earth in every branch of the Cavern, the most prevalent forms are hyæna, horse, and rhinoceros, and that their relative prevalence is indicated by the order in which they have been named.

The bones and teeth present much the same characters as those found in previous years. Thus, many of the latter are in jaws or fragments of jaws, destitute, as usual, of their condyles, and, in most cases, of the lower borders

also. Most of the specimens have an almost white colour, but some are of a dark hue; some are more or less coated with stalagmite, some are broken, some split, and very few have escaped the teeth of the hyæna. Amongst the finer and more remarkable specimens may be mentioned jaws of hyæna, canines of lion and bear, a left lower molar of *Elephas primigenius*, part of left lower jaw of rhinoceros, and a portion of a palate and both upper jaws of megaceros.

One of the canines of bear (No. 5537) is so peculiarly worn or cut, both on the crown and on the fang, and especially the latter, as to suggest the probability of human agency. On account of its strange aspect it was forwarded to Mr. G. Busk, President of the Royal College of Surgeons, F.R.S., V.P.L.S., &c., a member of the Committee, who thus remarks on it:—"The bear's canine (5537) is certainly very curiously worn if it be naturally so. The wearing of the crown part is possible enough, perhaps; but I cannot account for the apparently worn portion of the fang, which, of course, during life must have been protected from wear. But what could be the object of such an implement if it were manufactured? Perhaps a kind of gouge or chisel."—(Signed) GEORGE BUSK.

The mammoth's grinder (No. 5575) is almost perfect. Its crown measures 6 inches in length and 2·5 inches in greatest breadth. It was found September 13, 1871, in the third Foot-level, with 22 teeth of hyæna in parts of 5 jaws, 2 of rhinoceros, 1 of bear, with several large bones and fragments of bone. The bear's tooth just mentioned was a canine worn almost to the fang, which measures 1·7 inch in width.

The rhinoceros jaw (No. 5562), which has lost its condyles, but not its lower border, contains 4 consecutive molars, and is quite the finest specimen of the kind met with by the Committee. It was found September 2, 1871, in the third Level, with a tooth of bear, bones, and fragments of bone.

The jaws and palate of megaceros (No. 5646) contain 6 consecutive molars on the left side, and 5 on the right. This specimen was found October 10, 1871, in the third Level, with 1 tooth of rhinoceros, 1 of megaceros, 5 of horse, 6 of hyæna in parts of 2 jaws, bones, and splinters of bone.

Though Mr. MacEnery was not so fortunate as to find any flint implements in the Wolf's Cave, the Committee met with 5; and 4 of them are amongst the best specimens the Cavern has yielded.

No. 5563 is a white lanceolate implement, 2·8 inches long, ·85 inch broad, and ·2 inch thick. It has a strong subcentral longitudinal ridge on one surface, is slightly concave longitudinally and convex transversely on the other, reduced to an edge on both margins, rounded and rather blunt at one end, abruptly truncated at the other, and has apparently seen some service. It was found September 2, 1871, in the fourth Level, with 1 tooth of bear, 1 of rhinoceros, 3 of hyæna, 3 of horse, and 1 of ox.

No. 5571 is a pale grey flint implement of delicate proportions. It is 3·7 inches long, ·65 inch in greatest breadth, and ·1 inch in greatest thickness. It is longitudinally and transversely convex on one side, somewhat strongly concave lengthways, but slightly convex in the direction of its breadth on the other, has a long narrow oval form, three ridges on its convex side, a thin edge all round its perimeter except at one end which is rather blunt, and does not appear to have been used. It was found September 9, 1871, in the third Level, with 4 teeth of hyæna, 1 of rhinoceros, 1 of horse, 1 of ox, and fragments of bone scored with teeth-marks.

No. 5592 is a chert implement, rudely quadrilateral in form, 2·5 inches long, 2·2 inches broad, ·6 inch thick, and has apparently been used. It was

found September 20, 1871, in the first Level, with 2 teeth of horse and 1 of rhinoceros.

No. 5602 is a strongly proportioned chert lanceolate implement, 3·9 inches long, 1·1 inch broad, and ·4 inch thick. It is concave on one face, very strongly carinated on the other, truncated at one end, pointed but blunt at the other, and worked to an edge along its two margins. It was found September 22, 1871, in the fourth Level, with 4 teeth of hyæna, 2 of horse, and several fragments of bone.

No. 5656 is a somewhat irregular ovate chert tool, unequally convex on its two faces, 4·2 inches long, 3·3 inches in greatest breadth, and ·85 inch in greatest thickness. It has been wrought to an edge around its entire circumference, but not elaborately finished; at one small part near its broader end a portion of the original surface of the nodule from which it was formed remains, and it has apparently been much used. It was found October 13, 1871, in the third Level, but without any bones or teeth in the same Yard. Three implements of the same type have been mentioned in previous Reports *.

The Cave of Rodentia.—From the north-eastern corner of the Wolf's Cave, a passage, scarcely 5 feet long, about 5·5 high, and where narrowest not more than 5 feet wide, leads into a chamber measuring about 25 feet from east to west, and 20 from north to south. It was termed the "Cave of Rodentia" by Mr. MacEnery, who thus describes his researches in it:—"We now found ourselves in the midst of hundreds of Rodentia. Of their remains and dust the deposit was constituted, agglutinated together by calcareous matter into a bony breccia. It should have been premised that the stalagmite above them was about a foot and a half deep, regularly laminated and free from all adventitious matter. . . . . It suffered no disturbance or interruption from its first commencement. . . . . The remains of Rodentia were wanting in no part of the Cavern that we had yet examined, ... but here, in this grotto, they swarmed in countless multitudes. Not only had their tiny remains penetrated into every cleft and crevice of the rock, but they insinuated themselves even into the chambers of the large bones. The wolf's skull, in the passage, had its cavities charged and its surface incrusted over with a concretion of their bones. . . . . It was an interesting spectacle to behold myriads of minute animal remains congregated by the side of elephants, rhinoceroses, and hyænas in a common sepulchre. Heads generally crushed; lower jaws preserved. When a handful of this dust was thrown into water, hundreds of teeth rose to the surface, and it was by this means they were collected"†.

It will be seen from the foregoing quotation that here, too, the Committee were following Mr. MacEnery's steps. His labours, however, were on a less extended scale than in the Wolf's Cave. In the narrow trench to which he restricted himself, and which was not continuous, his excavations never extended more than 2 feet, and frequently not more than 18 inches, below the base of the Stalagmitic Floor. Connected with this Cave, moreover, there proved to be two recesses, which he did not enter; indeed he did not suspect their existence.

The Roof of the Cave of Rodentia slopes gently towards the north. Its general height above the bottom of the Committee's excavation is about 8 feet;

* See also 'The Ancient Stone Implements, &c. of Great Britain,' by John Evans, F.R.S., F.S.A., 1872, figs. 386, 387, p. 447.

† Trans. Devon. Assoc. vol. iii. pp. 244, 245.

and from this it varies but little, except in one or two places, whence masses of limestone have recently fallen. The Roof is fretted, and has occasional flues, extending tortuously upwards, and from 9 to 12 inches in diameter at the bottom, where they are largest. None of them contain any stalactitic or earthy matter.

The walls of the Cave are but little fretted, and their edges but slightly rounded.

Almost immediately on entering the Cave the workmen had to blast a large mass of limestone lying on the Stalagmitic Floor, and which in all probability deterred Mr. MacEnery from breaking ground there. A few yards further in, a portion of the south wall, certainly *in situ*, and without obvious indication of severance from the limestone stratum of which it was a part, was found to project a few feet beyond the general direction, and to have Cave-earth beneath it. This underlying deposit had been regularly removed as the successive Parallels were excavated. At length the entire mass, estimated at a ton in weight, fell and very nearly crushed the principal workman.

The Stalagmitic Floor, originally continuous across the entire length and breadth of the Cave, had in great part been broken up by the earlier explorers. Judging from the remnants of it still remaining, it was of the ordinary granular and laminated character, and from 3 to 12 inches in thickness.

Beneath this Floor the deposit was the common Cave-earth from top to bottom of the 4-feet sections, except in the northern corner of the Cave, where the Old Crystalline Stalagmitic Floor, *in situ*, formed its basis, and rose like a boss from beneath.

In the excavated deposits thrown aside in this Cave by Mr. MacEnery, the Committee found bones and teeth as usual, and a bronze gouge 3·2 inches long, and ·75 inch in diameter at the end intended for the reception of the haft. There can be little or no doubt that it lay on the Stalagmitic Floor before Mr. MacEnery entered the Cave, and that he failed to observe it.

The only object found in the Granular Stalagmitic Floor (that overlying the Cave-earth) was a fine *os innominatum* of a rhinoceros, No. 5743.

In the intact Cave-earth about 1000 teeth of various kinds of mammals were met with, and in the ratios shown in the following Table:—

TABLE IV.—Showing how many per cent. of the teeth found in Cave-earth in the Cave of Rodentia belonged to the different kinds of Mammals.

Hyæna	44 per cent.	Reindeer	1·5 per cent.
Horse	28 ,,	Elephant	1 ,,
Rhinoceros	9·5 ,,	Lion	1 ,,
Megaceros	4 ,,	Sheep	·5 ,,
Deer	4 ,,	Fox	1 tooth only.
Bear	3 ,,	Wolf	1 tooth only.
Ox	2 ,,		

In certain parts of the Cave the Cave-earth was found intact in every Level; in others the uppermost Foot-level only had been broken up, leaving the second, third, and fourth undisturbed; whilst in a third area the two lower Levels alone had not been touched. The second group occupied an area of but limited extent, and needs no further notice, but the distribution of the teeth in the first and third are shown in the following Tables:—

TABLE V.—Showing the distribution of the Teeth of the different kinds of Mammals in each of the four Foot-levels of thirteen Parallels of Cave-earth in the Cave of Rodentia.

	Hyæna.	Horse.	Rhinoceros.	Megaceros.	Bear.	Elephant.	Lion.	Deer.	Ox.	Reindeer.	Sheep.
No. of Parallels containing teeth in 1st Level	3	3	2	2	2	0	0	0	1	0	0
,, ,, ,, 2nd ,,	8	9	5	0	5	1	1	4	0	1	1
,, ,, ,, 3rd ,,	11	9	5	2	1	2	1	3	0	0	0
,, ,, ,, 4th ,,	2	5	3	1	1	1	0	1	1	0	0
,, ,, ,, all Levels	13	11	8	5	7	3	2	6	2	1	1
Total No. of teeth in 1st Level	13	7	3	2	2	0	0	0	2	0	0
,, ,, 2nd ,, ...	44	26	7	0	10	1	1	6	0	1	1
,, ,, 3rd ,, ...	38	24	6	2	1	3	1	8	0	0	0
,, ,, 4th ,, ...	6	17	4	1	1	1	0	2	1	0	0
,, ,, all Levels	101	74	20	5	14	5	2	16	3	1	1

TABLE VI.—Showing the distribution of the Teeth of the different kinds of Mammals in the third and fourth Foot-levels of fourteen Parallels of Cave-earth in the Cave of Rodentia.

	Hyæna.	Horse.	Rhinoceros.	Megaceros.	Wolf.	Lion.	Deer.	Ox.	Reindeer.
No. of Parallels containing teeth in 3rd Level	13	11	9	5	1	1	1	4	2
,, ,, ,, 4th ,, ...	11	9	5	1	0	0	0	2	1
,, ,, ,, both Levels ..	14	13	10	5	1	1	1	6	2
Total No. of Teeth in 3rd Level	64	39	18	11	1	1	1	7	3
,, ,, 4th ,, ...	68	25	7	2	0	0	0	2	1
,, ,, both Levels	132	64	25	13	1	1	1	9	4

In the material which Mr. MacEnery had excavated, examined, and thrown aside in this Cave, about 130 teeth were found, which may be apportioned as in the following Table:—

TABLE VII.—Showing how many per cent. of the Teeth found in the disturbed material in the Cave of Rodentia belonged to the different kinds of Mammals.

Hyæna..........	37	per cent.	Ox	3	per cent.
Horse	31	,,	Rabbit	3	,,
Deer............	12·5	,,	Reindeer..........	1	tooth.
Rhinoceros	8	,,	Wolf	1	,,
Bear............	3	,,	Fox..............	1	,,

It has already been mentioned that there were two recesses in this Cave into which Mr. MacEnery did not enter. One, in the north-east corner,

measuring 4 feet long by 4 feet broad, yielded 36 teeth of hyæna, 5 of deer, 4 of horse, 4 of rhinoceros, 2 of ox, a portion of an elephant's tusk, numerous bones, and 1 flint flake. The other, in the opposite corner of the Cave, measured 9 feet by 8 feet, and was found to contain 161 teeth of hyæna (many of them in parts of jaws, all having lost their condyles), 107 of horse, 40 of rhinoceros, 16 of deer, 10 of bear, 8 of megaceros (of which 5 were in part of a lower jaw), 5 of elephant, 5 of ox, 5 of sheep, 4 of lion, 1 of fox, a great number of bones, balls of coprolite, 1 flake of flint and 2 of chert.

The following are among the noteworthy specimens found in the Cave of Rodentia:—

Part of the left upper jaw of a bear (No. 5740), containing the last three molars, which are not much worn. This specimen is in a good state of preservation, and was found November 18, 1871, in the third Level of Cave-earth, with 2 teeth of hyæna, 1 of lion, and 1 of elephant.

Part of the right upper jaw of a bear (No. 5745), containing the last three molars, which are somewhat worn. This specimen, which is not well preserved, was lying with a portion of probably the same head in a corresponding condition, and containing 1 canine of great size. They were found November 20, 1871, in the second Level of Cave-earth, with 1 tooth of hyæna.

A canine of a bear (No. 5749), much worn, and having a fang 5·1 inches in girth. It was found November 22, 1871, in the second Level of Cave-earth, with 1 tooth of horse.

Portion of an elephant's tusk (No. 5764), measuring 10 inches long and 6·5 inches in girth—the largest specimen of the kind the Committee have met with in the Cavern. It is partially invested with stalagmite, to which a few small angular stones adhere, and on its surface there are teeth-marks of hyæna. It was found November 27, 1871, in the first Level of Cave-earth, with 2 teeth of hyæna, and gnawed fragments of bone.

A very small tooth of an elephant (No. 5774) with two diverging fangs. It was found December 2, 1871, in the fourth Level of Cave-earth. On account of its very small size and unusual fang it was forwarded to Mr. Busk, who has furnished the following remarks on it:—" $\frac{2}{5774}$, milk-molar of *Elephas primigenius*. As this tooth is only one half the size of the tooth usually, but erroneously, regarded as the m.-m. 1, I consider that it represents the very rare occurrence of a true m.-m. 1. If not, it is the smallest tooth of the kind I am acquainted with, except in the Maltese dwarf elephants (*vide* my paper in Zool. Trans. vol. vi. pl. 53. fig. 2). The proper dimensions of m.-m. 2 in *Elephas primigenius* are about ·8 inch × ·7 inch, and the smallest I have seen of *El. indicus* is ·6 × ·48; whilst a tooth in the Zebbug collection is ·4 × ·32, and the present one ·45 × ·3, or nearly the same. One objection, however, and that a strong one, to the present tooth being really m.-m. 1, arises from its having two divergent fangs, while the Zebbug tooth has only one, or two connate into one. This is a very curious specimen, and, as regards the elephant, of remarkable interest."—(Signed) GEORGE BUSK.

Several good specimens of coprolite were met with both in the Cave of Rodentia and the Wolf's Cave.

Five implements and flakes of flint and chert were found in the former Cave, but none of them rank amongst the best of the Cavern series; indeed one only (No. 5741) requires special description. It is a light grey flint, rudely oval in form, irregularly convex on both faces, 2·8 inches long, 2·4 inches broad, and ·95 inch in greatest thickness. Though it has undergone a considerable amount of chipping, and is reduced to an edge all round, it is by no means a well-finished, but was probably a very efficient, "scraper."

It was found November 18, 1871, with 5 teeth of hyæna, 2 of megaceros, 1 of horse, and 1 of rhinoceros, in the third Level of Cave-earth.

Besides the implements, there is a piece of chert having the form of a rude triangular pyramid, 3·2 inches high, its scalene base being 3·3 inches long and 1·2 inch broad. It was found November 30, 1871, with 2 teeth of hyæna, 3 of horse, and 1 of ox, in the third Level of Cave-earth. Its form is scarcely indicative of an artificial origin; and though its edges are somewhat rounded, it does not seem possible for it to have been transported by natural agency from the nearest locality in which such material is now found *in situ*, without being much more rounded than it is.

Before proceeding to another branch of the Cavern, the Committee would remark that they commenced their investigation of the Wolf's Cave on July 12, 1871, and from that time until they had reached its termination, as well as that of its offshoot, the Cave of Rodentia (a period of nearly six months), they cherished the hope that, like Mr. MacEnery, they might find some remains of *Machairodus latidens*. During their progress they were daily face to face with their energetic predecessor's labours, and from time to time met with the tools with which they were performed*; but they had finally to leave the two Caves on December 30, 1871, with a feeling of great disappointment that neither amongst the many hundreds of specimens which Mr. MacEnery had left in his broken ground, nor in the Cave-earth remaining intact beside and beneath his diggings, had they met with any trace of the great object and hope of their search.

MacEnery states that he found the famous canines "in diluvial mud mixed with teeth and gnawed bones of rhinoceros, elephant, horse, ox, elk, and deer, with teeth and bones of hyænas, bears, wolves, foxes, &c."†, and that he subsequently discovered an incisor of the same species in the same bed‡. It will be seen from Table III., given above, that, with scarcely any other exception than that of *Machairodus*, such an assemblage of remains as he enumerates was actually found by the Committee in the very soil which he had examined and cast aside; and from Table I., that of the animals in his list, just quoted, the great sabre-toothed Felis was the only one which failed to present itself when the Committee broke up the undisturbed Cave-earth lying below that which yielded the canines and incisor. When to this it is added that the most careful search by the Committee failed to detect in the Cave-earth which they excavated any remnant of the older Cavern deposit, and that MacEnery was struck with the fact that, though "delicately edged," the canines were found quite uninjured in the midst of the shattered bones §, a strong case seems to be made out in favour of the propositions that *Machairodus* belonged to the Devonshire Cave-earth fauna, and that his remains found in Kent's Cavern were not redeposited fossils.

The Charcoal Cave.—Two passages open out of the south-west corner of the Sloping Chamber, opposite the entrance of the Wolf's Cave. The more important is of considerable length, and leads in a south-westerly direction to a series of large chambers, in which the Committee have not yet undertaken any researches. Mr. MacEnery designated this the "Long Arcade."

Very near its mouth is the entrance of the second passage, to which, for a

* The tools were two hammers, a small chisel, a trowel, and an iron scraper. It cannot be necessary to state that these mementos of him who first made the Cavern famous have been carefully preserved.

† See "Plate F," 'Cavern Researches,' edited by E. Vivian, Esq., 1859.

‡ See Trans. Devon. Assoc. vol. iii. p. 370. § Ibid. p. 294.

reason which will shortly appear, the Superintendents have given the name of the "Charcoal Cave." This passage the Committee proceeded to explore before undertaking the Arcade.

It extends on the whole in a southerly direction for a distance of upwards of 50 feet, varying from 5 to 13 feet in breadth, and throughout the first half of its length maintaining a tolerably uniform height of from 9 to 10 feet. At 16 feet from the entrance it sends off a branch in an easterly direction, and at 26 feet a second branch towards the south-west; resolving itself, in short, into three passages, which ultimately reunite, and may conveniently be termed the "Northern," "Central," and "Southern" branches. They have all, but especially the northern, the aspect of long-continued watercourses fretted by the subsequent and unequal action of acidulated water. Mouths of "flues" present themselves in the roofs and walls; but none of them have any traces of earthy matter, and few are lined with stalactite. The branches are subject to a very copious drip very soon after rains, but no portion of it enters through the flues just mentioned.

At 18 feet from the entrance of the Cave a thin layer of black matter, among which charcoal was conspicuous, was observed lying on the surface of the Stalagmitic Floor, where it covered an area of about 2 square feet. It was thought to be probably the remains of a fire kindled by some recent visitors to the Cavern, though the place seemed an unlikely one for such a purpose, the roof being no more than 4 feet above the floor before the excavation, and the narrow passage being very seldom entered by visitors. The whole of the material was carefully collected, and, on being washed and examined, yielded the following assemblage of objects:—Small rough pieces of stalagmitic matter; bits of charcoal, some of them incorporated in the stalagmitic matter just mentioned; upwards of a dozen small pieces of very coarse friable pottery, of a reddish colour, without any trace of ornamentation, and in all probability parts of one and the same vessel; two unworn lower "wisdom teeth" of a human subject; a few entire phalangeal bones, apparently of an individual barely mature; part of an ulna, of a pelvis, of a vertebra, of ribs, and numerous small fragments of bone; an almost perfect left lower jaw of a fox, containing the canine tooth and five molars; a few incisors and bones of small rodents.

In accordance with the practice invariably followed since the commencement of the exploration, the water in which the objects just mentioned were washed was passed through a fine sieve for the purpose of detecting minute objects of interest. This water was almost black from the fine matter held in suspension, and which, on being deposited and dried, proved to be fine silt coloured with charcoal.

As earlier explorers of the Cavern had in one place in this Cave attempted to break through the Stalagmitic Floor at a point further in than the spot occupied by the black material, and must have frequently trampled on it, there is no difficulty in accounting for the broken condition of the pottery, the charcoal, and most of the bones. It is scarcely necessary to observe that the Charcoal Cave takes its name from the patch of black matter just described.

Mr. Charles Rodway, a distinguished dentist of Torquay, to whom the human teeth mentioned above were submitted, was so good as to furnish the following note respecting them:—

"Torquay, June 11, 1872.

"My dear Sir,—I have examined the two teeth you brought me, and they are right and left inferior '*dentes sapientiæ*' of a human being. They

are the teeth of a subject between the age of 15 and 20 years, judging from the undeveloped state of the roots, which later in life would be longer, with the pulp-cavity at the apices considerably smaller. I notice upon the lingual surface of the left tooth what I take to be a deposit of salivary calculus, which leads me to suppose that they were already erupted from the gum, although not sufficiently risen to have been used in mastication, as the enamel on the masticating-surface does not appear to have been subjected to friction. It would be impossible to say whether they are the teeth of a male or female; but from their strong likeness they are unquestionably the teeth of the same person.

"Yours truly,

(Signed) "CHARLES RODWAY, S.D., Li. R.C.S."

With the exception of the jaw of a fox, and the incisors and bones of rodents, all the osseous remains were believed by the Superintendents of the Exploration to be those of a human subject of about the age indicated by the wisdom teeth, and were all forwarded to Mr. G. Busk, who has furnished the following Report on them, confirming, with a few exceptions, their human character. The specimens were twenty in all, and were numbered $\frac{1}{5871}$, $\frac{2}{5871}$, and so on.

Mr. Busk's Report.

"No. $\frac{1}{5871}$. Fragment of left ilium; probably female; age unascertainable.

"2. Not human.

"3. The sternal end of a human clavicle.

"4. First phalanx of third finger, right hand; entire, but with the epiphysial line of junction quite distinct; age 18 to 20.

"5. Portion of body of lumbar vertebra, showing that the epiphyses were ununited; age the same.

"6. A fragment of the sacrum.

"7. First phalanx of fourth finger, right hand, with the epiphyses detached.

"8. Second phalanx of right thumb.

"9. Upper end of right ulna, of rather peculiar form; the peculiarity consisting in the straightness of the posterior angle and the breadth of the square anterior face. Epiphyses quite united; but as this union takes place at 16 years, the bone probably belonged to the same individual as the above.

"10. Shaft of humerus (?) of —— (?). Not human.

"11. Fragment of second right metacarpal.

"12. Distal portion of first metacarpal, or phalanx of thumb.

"13. Fragment of the shaft of a clavicle, of slender make.

"14. Fragment of the left ischium of a young ruminant of the size of the ibex, or a large goat; but may be by chance a young red-deer—not reindeer, nor fallow-deer, nor roebuck.

"15. Right cuneiforme bone.

"16. Right pisiform bone.

"17. First phalanx of fourth toe.

"18. Second phalanx of fifth toe.

"19. Third phalanx of third finger.

"20. Second phalanx of toe.

(Signed) "GEORGE BUSK."

"32 Harley Street, July 29, 1872."

The Superintendents incline to the opinion that, since the age of the subject to whom Mr. Busk ascribes the bones harmonizes with that of the person

to whom Mr. Rodway says the teeth belonged, all the remains are portions of the same skeleton, and that they had been preserved in a cinerary urn of which the potsherds found with them were fragments.

There was a continuous Stalagmitic Floor from the entrance of the Charcoal Cave to 19 feet within it, except at one place, where it did not quite extend from wall to wall. In the next 5 feet the Cave-earth was without any covering, but at 25 feet from the entrance a floor again presented itself. It was of the usual character, varied from 2 to 12 inches thick, and near the entrance there was in it, about 2 inches below the surface, a thin layer of carbonaceous matter.

In the northern branch the floor was everywhere continuous, and varied from 18 inches thick at the entrance to 1 inch at the inner end. In the central branch the floor was but partial, never exceeded 9 inches thick, and was occasionally no more than a mere film. In one or two instances pieces of Old Crystalline Floor were incorporated in it. There was very little floor in the southern branch.

Remnants of an old floor *in situ*, extending from wall to wall, presented themselves in each of the branches, always at some height above the Cave-earth. They were indications, of course, of the former existence, and at least partial dislodgement, of a deposit older than the Cave-earth, and which there attained a higher level. The most considerable of them was in the central branch: it was from 9 to 10 feet long, 3 inches thick; its upper surface was 1·5 foot below the limestone roof, and its lower surface 4 feet above the granular Stalagmitic Floor, the spaces between it and the roof above, and the ordinary floor below, being quite unoccupied. The remnants in the other branches differ from this in their measurements only.

With exceptions in portions of the central and southern branches, to be noticed immediately, the mechanical deposit in the Charcoal Cave was true Cave-earth. At the entrance, and for about 11 feet within, it contained an unusually great number of fragments of limestone from top to bottom of the section. Beyond the point just specified, up to 18 feet from the entrance, such fragments were rare, except in the uppermost Foot-level, where they still abounded; their place below being taken by a few pieces of red grit, some of which were fossiliferous, whilst the Cave-earth became very sandy.

From the first to the second bifurcation of the Cave, as well as for a few feet within each branch, the Cave-earth was no more than from 1 to 3·5 feet deep, and rested on a continuous, but very uneven, limestone floor—an instance, and probably the only one yet known in the Cavern, of this floor being reached.

In the northern branch the deposit was true Cave-earth throughout. In the central one the Cave-earth contained a few pieces of Old Crystalline Floor, and throughout the innermost 10 feet rested immediately on the old dark red Breccia, found elsewhere in the Cavern beneath the Crystalline Stalagmitic Floor. In the southern branch nothing but true Cave-earth was found from the entrance to 8 feet within it; but beyond that to the end, a distance of 17 feet, from the base of the section to 2·5 and even 3 feet above it, the entire accumulation was the old dark red Breccia, rock-like in its cohesion, continuous from wall to wall, and clearly *in situ*.

It may be well at this point to give a brief recapitulation of the facts as they presented themselves in ascending, but not necessarily chronological, order, in the same vertical section, in the central and southern branches:—

First, or Lowest. ·Dark red rock-like Breccia, at least largely composed of angular, subangular, and rounded fragments of Devonian grit, derivable

from the adjacent loftier hills, but not from the comparatively low one in which the Cavern occurs. Its depth is unknown, as its base has not been reached.

Second. Cave-earth, consisting of a somewhat light red loam and generally about 50 per cent. of angular fragments of limestone, with an occasional pebble not derivable from the Cavern-hill. Its depth was variable, but never less than 1 foot.

Third. A floor of granular Stalagmite, from 1 to 18 inches thick.

Fourth. An unoccupied space from 1 to 4 feet high.

Fifth. A floor of Crystalline Stalagmite from 3 to 4 inches thick.

Sixth. An unoccupied space from 1 to 3·5 feet high.

Seventh. The limestone roof of the Cave.

Were we to speculate on the history of the Charcoal Cave as indicated in the facts just described, we should find ourselves taken back to the time when it was formed, not by any convulsion, but by the actual and probably gradual removal of the limestone which once filled the entire space between the walls, as is shown by the unfissured roof and the continuous limestone floor.

Secondly, so far as can be ascertained, the introduction of angular, sub-angular, and rounded pebbles of dark red grit, with sandy mud derived from their attrition, until the Cave and its branches were filled almost to the roof.

Thirdly, the introduction of materials from without having ceased, the Breccia which had accumulated was hermetically sealed up with a cake of Crystalline Stalagmite, from 3 to 4 inches thick—the result of the slow solution and precipitation of calcareous matter.

Fourthly, the Crystalline Stalagmite was partially broken up, and a portion of the Breccia was dislodged, the removal being more complete in some parts than in others.

Fifthly, again there was introduced a mechanical deposit, but instead of dark red grit and sandy mud, it consisted of a light red loam and angular fragments of limestone of various sizes. It did not attain to so great a height as the previous deposit of dark red material.

Sixthly, a floor of Stalagmite, differing from the former in being granular instead of crystalline, was formed on the red loam or Cave-earth, at a lower level than that which sealed up the Breccia.

Seventhly and lastly, this latter floor being completed, there was placed on it a small cinerary urn, containing human bones and bits of charcoal.

But to return. The deposits in the Charcoal Cave were by no means rich in osseous remains. The granular stalagmite yielded a few unimportant bones only, and in the Cave-earth there was but a comparatively small number of bones, and no more than 85 teeth. The latter belonged to different kinds of mammals in the ratios shown in the following Table :—

TABLE VIII.—Showing how many per cent. of the Teeth found in Cave-earth in the Charcoal Cave belonged to the different kinds of Mammals.

Horse	33	per cent.	Bear	3·5	per cent.
Hyæna	29·5	,,	Wolf	2·5	,,
Fox	12	,,	Elephant	1	,,
Rhinoceros	10·5	,,	Ox	1	,,
Badger	6	,,	Sheep	1	,,

There were but thirteen of the Parallels consisting of Cave-earth from top to bottom of the 4-feet sections which contained teeth, and these amounted to no more than 31 in number. Their distribution is shown in the following Table :—

TABLE IX.—Showing the distribution of the Teeth of the different kinds of Mammals in each of the four Foot-levels of thirteen Parallels of Cave-earth in the Charcoal Cave.

	Horse.	Hyæna.	Rhinoceros.	Bear.	Elephant.	Ox.	Sheep.
No. of Parallels containing teeth in 1st Level	4	2	1	1	0	0	1
,, ,, ,, 2nd ,, ...	2	2	0	0	0	0	0
,, ,, ,, 3rd ,, ...	1	3	0	0	1	0	0
,, ,, ,, 4th ,, ...	2	2	1	0	0	1	0
,, ,, ,, all Levels	7	7	2	1	1	1	1
Total No. of teeth in 1st Level	7	2	1	1	0	0	1
,, ,, 2nd ,, ...	4	2	0	0	0	0	0
,, ,, 3rd ,, ...	3	3	0	0	1	0	0
,, ,, 4th ,, ...	2	2	1	0	0	1	0
,, ,, all Levels	16	9	2	1	1	1	1

The following may be mentioned amongst noteworthy bones found in the Charcoal Cave:—The distal end of a tibia (No. 5906), an astragalus, and the proximal end of an os calcis of horse, all inosculated in true anatomical position as when clothed with flesh, thus intimating that they were so clothed when lodged where they were found. The fractured end of the tibia affords decided evidence of the powerful jaws of the hyæna. With the specimens were found another distal end of a tibia of horse, a metatarsus of horse, a metatarsus of reindeer, part of an antler, a rather small astragalus, and a gnawed bone. They were lying but little below the surface of the Cave-earth, where it was not more than 1·5 foot deep, almost in contact with the roof of the southern branch, and deposited on the old dark red Breccia; and they were extracted June 6, 1872, in the presence of one of the Superintendents.

In a precisely similar situation, and but one foot from the objects just named, a metacarpus of horse and a large atlas were found two days after.

On April 22, 1872, there were found on the surface of the Cave-earth upwards of 600 bones of rodents all lying together; and on the 11th of the same month nearly 800 small stalagmitic bodies, which may be likened to rather large, ill-shapen, rugose marbles, were found in a heap on the Cave-earth, in a small recess in the wall of the southern branch, with two hazel-nut-shells and a piece of bone. On May 17 a similar but smaller heap, containing about 100 such "marbles," with a toothless fragment of jaw, was met with in a position precisely like the former. Several coprolites were found in the Charcoal Cave.

One small flake of white flint (No. 5899) was found in the southern branch on May 22, 1872. It may be dismissed with the remark that it lay in the first Level of Cave-earth with 2 teeth of hyæna.

Bones and teeth were found in the old dark red Breccia in the central and southern branches. The bones were much broken in digging them out, on account of the rock-like character of the Breccia. The teeth, like those found in the same deposit in other parts of the Cavern, were all of them those of bear.

In their Fifth Report (Exeter, 1869) the Committee called attention to a flake of flint found in the Breccia in the "Water Gallery," and pronounced by Mr. John Evans, F.R.S., a Member of the Committee, to be not only of

artificial origin, but to have been used by man *; and they ventured on the opinion that, from its being coeval with the Breccia (which must have been laid down long before the deposit in which, so far as the Cavern evidence goes, the first traces of the Cave-hyæna, Cave-lion, mammoth, and their contemporaries were met with), it was anthropologically by far the most important object the Cavern had yielded. From that time the Committee have had no opportunity of investigating this old Breccia, and hence no announcement of further discoveries of the kind were looked for in their Sixth or Seventh Reports (1870 and 1871). They are now, however, enabled to return to the subject, and to state that the Breccia has yielded two additional flint implements.

The first of these (No. 5900) was found May 22, 1872, in the southern branch, from 1 to 2 feet deep in the Breccia, in which it was firmly imbedded; and over this was an accumulation of typical Cave-earth, having no Stalagmitic Floor either above or below it. There were no bones found near the implement; but vertically above it, in the Cave-earth, were the small flake of white flint and the 2 teeth of hyæna just mentioned. It is rude in form, rather over 5 inches in greatest length, scarcely 3 inches wide, and about 1·5 inch in greatest thickness. It exhibits a small portion of the surface of the nodule from which it was made, is of a dull cream colour, and its weight is less than that of ordinary flints of the same size; in these respects resembling some of the tools found in the Windmill-Hill Cavern at Brixham.

All the dimensions of the second implement (No. 5903) slightly exceed those of that just described. Its colour is a pinkish cream; one of its surfaces is nearly flat, whilst the other is very convex, and retains much of the surface of the original nodule. One of the Superintendents, who assisted to extract it, had the opportunity of studying it before any attempt was made to move it. The Breccia was compactly cemented together, and the implement was firmly imbedded in it, at 1 foot below its surface, above which was Cave-earth to the depth of 27 inches, and, without being covered with stalagmite, reaching within 3 inches of the roof; in other words, the united thickness of the two deposits overlying the tool was 39 inches. It was distinctly observed to be fractured; and as the severed portions were in such close contact as to render the line of junction almost microscopic, it had obviously been broken where it lay. Every care was taken in its removal; but on being extracted it fell into three pieces, one of which remained firmly attached to and incorporated in a lump of the Breccia. The fractured surfaces showed that its colour was whitish throughout, and that its texture was granular. It was found May 27, 1872, in the southern branch of the Cave, about 2 feet from the specimen just described (No. 5900), and, like that, had no bones near it.

The excavation of the Charcoal Cave and its branches was completed July 7, 1872, the labour of 4·5 months having been expended on it.

The Long Arcade.—The principal passage opening out of the south-west corner of the Sloping Chamber, as already mentioned, was termed the Long Arcade by Mr. MacEnery †, and the "Hyæna Cloaca Maxima" by Dr. Buckland ‡. It has a direction towards south-west, and is the great thoroughfare to the "Labyrinth," "Bear's Den," and "Cave of Inscriptions." Its exploration is at present in progress. Up to the end of July about ten weeks' work had been expended on it; but a very large amount remains to be done there. Mr. MacEnery had commenced the exploration of the Arcade, but meeting with fewer fossils than he hoped, soon abandoned it §.

* See Report Brit. Assoc. 1869, pp. 202, 203.

† See Trans. Devon. Assoc. vol. iii. p. 303 (1869). ‡ Ibid. p. 237. § Ibid. p. 290.

At its entrance this branch of the Cavern is about 17 feet in width and 13 in height. The roof is the naked limestone, much fretted or honeycombed. The Granular Stalagmitic Floor was continuous in every direction and of very great thickness. Its surface, for some distance, was occupied by a series of natural basins, bounded by stalagmitic walls rising above the general level of the floor. They varied in depth from an inch to fully a foot, and in wet seasons were constantly full of water. Similar basins occur in other parts of the Cavern, but those at the mouth of the Arcade (the great thoroughfare) have attracted a large amount of attention. Mr. MacEnery described them as "encircled with wavy walls, rivalling the most exquisite works in pastry"*. When breaking up the floor it was observed that the bottoms of the basins were formed of a softer looser stalagmite than that composing the walls, and that these dissimilar characters extended vertically downwards through the entire "Floor." Charcoal has been found in a few of them, and one contained two or three bones.

At the western wall of the Arcade, and several feet from it, the Stalagmitic Floor was never less than 4, and not unfrequently upwards of 5 feet thick; but at the eastern wall it rarely measured more than 2 feet. The uppermost 6 inches were frequently of a dirty reddish colour, as if soil-stained; but at greater depths it was very pure, often granular, occasionally flaky, and everywhere distinctly laminated.

At something more than a foot from the bottom of the Floor, there was found in every section a roughly horizontal, continuous, black line, extending from the western wall of the Arcade to a distance, in one instance, of 7 feet, generally about a quarter of an inch thick, but never exceeding half an inch. It was due to the presence of charcoal, and, of course, represented a thin sheet of that material. It was very carefully watched as the Floor was broken up, but yielded no trace of bone or of any substance besides the charred wood.

This "Charcoal Streak" was observed and studied by Mr. MacEnery, who, attaching great chronological importance to it, described it no less than four times †. The portion of the Floor in which he found it was not more, at most, than half the thickness of that recently broken up by the Committee. From his description it appears to have been horizontal, midway from the surface to the bottom of the stalagmite, from 1 to 2 inches thick, about 5 feet in greatest length in any section, composed of charred wood and straw, and to have contained the following objects imbedded in it:—Small polished pebbles of white flint, shells, two portions of the jaw, a tusk, and some phalanges of boar, the under jaw of a badger, bones of rabbits and rats, and cylindrical bones which Dr. Buckland, who extracted them, assigned to deer. The latter were half-roasted, and, with the exception of the jaws of the boar, all the bones had been more or less exposed to the action of fire. No extraneous objects of any kind were found in the Floor above or below the "Charcoal Streak."

The Committee have been more fortunate, having met with bones in other parts of the stalagmite, but all of them below the black line. The most noteworthy of these are a tooth of deer (No. 5818), a large vertebra (No. 5951), and a well-worn tooth of hyæna (No. 5969). In the same deposit a piece of black flint (No. 5938) was found July 18, 1872.

Mr. MacEnery's diggings in the Cave-earth at the entrance of the Arcade had in some places been carried to a depth of 3 feet below the Stalagmitic Floor, thus leaving the fourth Foot-level intact. They gradually became less and less deep, until at 12 feet from the entrance they ceased entirely. This excavated material has been carefully reexamined, but contained very few specimens.

* Trans. Devon. Assoc. vol. iii. p. 236. † Ibid. pp. 235, 236, 261, 291, and 335.

The deposit underlying the Stalagmitic Floor was typical Cave-earth, having no peculiar characteristics. Up to the end of July no trace of the Breccia (the older deposit) had presented itself, either *in situ* or in incorporated fragments. It has not proved to be very rich, nor has it been remarkably poor, in bones and teeth; and it has yielded two flint implements. It is believed, however, that the lack of abundance will be found to be fully compensated by the character and value of at least one of the specimens.

One of the implements (No. 5819) is a somewhat mottled white flint, rather irregular in form, flat on one face, doubly carinated on the other, 3·3 inches long, 1·1 inch in greatest breadth, and ·4 inch where thickest. It was found in the first Foot-level of Cave-earth with a portion of a grey flint nodule, apparently fractured artificially.

The second implement (No. 5829) is a bluish-grey flint, semilunar in outline, 2·5 inches long, 1·5 inch broad, and fully ·5 inch in greatest thickness. It was found, with a tooth of hyæna and a tooth of horse, in the third Foot-level of Cave-earth.

Up to the end of July 120 teeth and a considerable number of bones, belonging to various kinds of mammals, had been met with. As the exploration of the Arcade is not completed, it is perhaps undesirable at present to exhibit the distribution of the teeth in a tabular form. The hyæna, as usual, takes the lead, and is followed by the horse and the rhinoceros in their usual places.

Though, amongst the animal remains, several good specimens have been met with in the branch of the Cavern at present under notice, only two of them require special mention. One of these (No. 5968) is the right lower jaw of a young bear, and, what is very unusual in the Cavern, perfect in all its parts. Such, however, was its fragility that it was broken in taking it out of the deposit. It was found July 30, 1872, with an additional canine of a young bear (in all probability belonging to the same individual) and a tooth of elephant, in the third Foot-level of Cave-earth, over which the Stalagmitic Floor was 5 feet thick.

The other specimen (No. 5962) is a well-marked incisor of *Machairodus latidens*, found July 29, 1872, with the left lower jaw of bear containing one molar, in the first or uppermost Foot-level of Cave-earth, having over it the Granular Stalagmitic Floor 2·5 feet thick. It answers admirably to the following description given by MacEnery of the incisor he found:—"The internal face of the enamel is fringed with a serrated border. This tooth is distinguished further by two tubercles or protuberances at the base of the enamel from which the serration springs, and describes a pointed arch on the internal surface. . . . . The body of the tooth in this specimen is not compressed but rounded" *. He adds, "Whether this belongs to an inferior species of *U. cultridens*, or [is] simply the incisor anterior to the canine of the larger species of *U. cultridens*, I am not able to pronounce with certainty. If merely the incisor, it is still interesting, as it serves to show that the serrated character is not confined to the canines, and that the rest of the teeth, and consequently the frame, are marked by a peculiar conformation."

A glance at the new specimen suffices to explain why Mr. MacEnery was uncertain respecting the canine or incisive character. Indeed the workmen sent it to the Secretary of the Committee under the belief that it was the canine of a wolf, it being partially covered with Cave-earth; and its true character was detected whilst it was being washed, August 5, 1872.

MacEnery states that his incisor, which unfortunately cannot be traced, was "about an inch long" *—the expression, in all probability, of a rough

* Trans. Devon. Assoc. vol. iii. p. 370.

guess, and not of actual measurement. The incisor from the Cavern (doubtless that discovered and described by MacEnery) figured by Professor Owen in his 'History of British Fossil Mammals, &c.'* very nearly corresponds in size with its homologue just found. The new specimen is slightly longer in the crown, and somewhat thicker in the fang.

The Committee cannot but feel that their thanks, as well as those of all palæontologists, are due to the Committee of the Geological Section for having, year after year from 1864 inclusive, cordially applied for a grant from the funds of the Association for the exploration of the Cavern, to the Committee of Recommendations for having recommended the successive applications, and to the General Committee for having annually voted the sums applied for. One of the hopes of the Cavern Committee, in commencing their researches, was that they might find some traces of *Machairodus*. This they have never abandoned, though year after year passed away without success; and they cannot but express their gratitude to the body whose patience and liberality has enabled them to continue their labours until this hope was realized. The greater part of this Report was written before the discovery was made; and had the work ceased on July 28, 1872, those who always declined to believe that *Machairodus* had ever been found in Kent's Cavern, would have been enabled to urge, as an additional argument, the fact that the consecutive, systematic, and careful daily labours of 7 years and 4 months had failed to show that their scepticism was unreasonable. This great accumulation of negative evidence has been for ever set aside, and all doubt of Mr. MacEnery's accuracy for ever removed, by the discovery the Committee have now had the pleasure to announce.

They can now announce also that *Machairodus latidens* and man were contemporaries in Britain; for even if, notwithstanding the great array of facts to the contrary, the former should prove to have belonged to the era of the Breccia, and not to that later time represented by the Cave-earth, the two flint implements found in the Breccia, to which attention was called in a previous part of this Report, as well as that produced and described at Exeter in 1869, take man back to that earlier period also.

Report of the Committee appointed for the purpose of promoting the Foundation of Zoological Stations in different parts of the World.

The Committee beg leave to report that, as stated in the Report of last year, the Zoological Station of Naples will be ready and in working order in the beginning of January 1873, the progress of the construction being such as to enable Dr. Dohrn to make this assertion.

This undertaking has received much official and private assistance, not only from public authorities, but in a very high degree from private persons. The Committee have much pleasure in acknowledging especially the extraordinary services rendered by Mr. W. A. Lloyd, of the Crystal-Palace Aquarium, in giving every assistance to Dr. Dohrn, as far as technical difficulties are concerned.

Special care has been taken to secure donations to the future library of the Station. The eminent firm of Engelmann, in Leipzig, has presented all its works on Biology not previously possessed by Dr. Dohrn. Vieweg, in Brunswick, has also sent all his publications on Biology. Theodore Fischer, in Cassel, has done

* A History of British Fossil Mammals and Birds. By Richard Owen, F.R.S., F.G.S., (1846), p. 182, fig. 70.

the same. Important donations are promised from Dr. Alexander Agassiz, Cambridge, Mass., comprehending the publications of both his father and himself.

To secure the development of the library on a greater scale, it will be necessary to make general applications. For this purpose, Dr. Dohrn, assisted by several of the greatest German publishing firms, is preparing an appeal to all German publishers, and hopes also to succeed with a like demand in Italy. The Committee hope that the British Association will lend its moral assistance to a similar demand in this country, not only by granting a complete set of its own publications, but by recommending a similar act to other scientific bodies and private persons.

The Committee are further glad to announce that some Steam Navigation Companies are prepared to grant a free passage to the Naturalists, and free transport for the goods sent to or from the Zoological Station.

Dr. Dohrn contemplates a new step for the purpose of securing a larger income for the Naples Station. He is about to offer to several Governments, Universities, and Scientific Bodies working-tables in the Laboratory of the Station for a certain annual sum. The payment of this sum would confer upon the subscribing Government, University, or Society the right of appointing naturalists, who, on presenting a certificate to the administration of the Station, would be furnished with a working-table and admitted to a participation in all the other very extensive advantages of the Station.

The Committee think it well earnestly to advocate this new step of the administration of the Naples Station, the more so as it lessens the burden of the single naturalist, enabling even such as are destitute of means to profit by the manifold advantages of the Station, while it guarantees a fixed annual income to the latter, which would be employed in improving the technical and other means of investigation.

Fourth Report on the Fauna of South Devon. By C. Spence Bate, *F.R.S.*

In presenting to this Association the Fourth Report of the Marine Fauna of the South Coast of Devon and Cornwall, it cannot be supposed that any great increase of novelties, either in species or genera, can be added to the forms known; and to recapitulate those already reported is unnecessary. My attention therefore has been directed more especially towards the development and habits of animals that have fallen within my range of observation. Facility has been given in this direction by the establishment at Plymouth, under my suggestion and plan, of a marine pond for the purpose of keeping and storing animals for the aquarium at the Crystal Palace. Already it has given us opportunities of observing the habits of animals that could scarcely be obtained under any less favourable circumstances. These opportunities will become still more numerous and valuable as the conditions of the pond become more adapted to deep-sea species.

The pond is formed out of a deep gully in the limestone shore, and much of it extends far into a cave beneath the cliff. The pond is irregular in shape and depth, and affords many crannies, nooks, and corners for animals to live or take refuge in. At the entrance, where the water is deepest, the width of the pond is about eleven feet, but at other places it is more than double that extent; and when the sea rises to the higher spring-tides the length of the pond extends upwards of eighty feet from the wall that separates it from the waters of the Sound. The rocks, which were formerly covered with

Fucus, are now matted with grass-green Algæ; and with the change the water has lost its foul and stagnant appearance, and become pellucid and clean.

The following fish have been taken on the coast since the last Report, and with those already mentioned form a tolerably perfect list of the fish of the southern coast of Devon and Cornwall:—

List of Fishes taken off Plymouth.

(The English names are from Couch.)

	Frequency.	Locality.
Raia marginata (Bordered Ray)	Common.	
Raia spinosa	Common.	
Squatina congelus (Monk-fish)	Common	Sound.
Syngnathus (several species)	Common	Estuaries.
Anguilla conger (Conger)	Common	Sound.
Lepidogaster cornubiensis (Cornish Sucker)	Not common; common in some parts.	„
Lepidogaster bimaculatus (Doubly-spotted Sucker)	Not common	„
Solea vulgaris (Sole)	Common	„
Rhombus punctatus, young (Müller's Topknot)	Common	Estuaries.
Platessa	Abundant	„
Motella vulgaris (Three-bearded Rockling)	Abundant	„
Merlangus pollachius (Pollack)	Abundant	Sound.
Morrhua lusca (Bib, or Whiting Pout)	Abundant	„
Morrhua minuta (Bower)	Abundant	„
Morrhua vulgaris (Whiting)	Common	„
Clupea harengus (Herring)	Occasionally	Estuaries.
Alosa finta (Shad, Maid)	Occasionally	„
Belone vulgaris (Garfish)	Common	Sound.
Scomberesox saurus (Skipper)	Once only	Under the Hoe.
Labrus maculatus (Ballan Wrasse)	Abundant	Sound.
Labrus mixtus, ♂ & ♀ (Cuckoo Wrasse)	Not common	„
Crinilabrus melops (Corkwing)	Abundant	„
Crinilabrus rupestris (Goldsinny)	Abundant	„
Acantholabrus exoletus (Rock Cook)	Abundant	„
Callionymus lyra, ♂ & ♀ (Yellow Skulpin)	male only in Mid Channel, female plentiful	„ Estuaries.
Gobius niger (Rock Goby)	Abundant	Sound.
Gobius ruthinsparri (Two-spotted Goby)	Abundant	„
Gobius unipunctatus (One-spotted Goby)	Abundant	Estuaries.
Blennius montagui (Montagu's Blenny)	Uncommon	„
Blennius gattorugine (Gattorugine)	Not plentiful	Sound.
Blennius pholis (Shanny)	Abundant	„
Murænoides guttata	Abundant	„
Mugil capito (Grey Mullet)	Abundant	Estuaries.
Atherina presbyter (Smelt)	Abundant	„
Zeus faber (Doree)	Not common	„
Capros aper (Boar-fish)	Common	Offing.
Scomber scombrus (Mackerel)	Common	Sound.
Pagellus centrodontus (Bream)	Common	„
Gasterosteus spinachia (15-spined Stickleback)	Common	„
Cottus bubalis (Lucky Proach)	Common	Estuaries.
Aspidaphorus cataphractus (Armed Bullhead)	Common	„
Trigla cuculis (Red Gurnard)	Common	Offing.
Trigla hirundo (Tub-fish)	Common	Estuaries.
Trigla gurnardus (Grey Gurnard)	Common	„
Mulus surmuletus (Surmullet)	Not common	„
Trachinus draco (Greater Weever)	Common	Offing.
Trachinus vipera (Viper Weever)	Not common	Estuaries.
Serranus cabrilla (Coruber)	Not common	„
Labrax lupus (Bass)	Common	Sound.

Most of these have been confined in the pond, where they generally appear to acclimatize themselves readily. The exceptions appear to be among those species whose habits are of an erratic character, as the Mackerel (*Scomber scombrus*). Several specimens of this species have been placed in the pond, where the imprisonment alone seemed to operate prejudicially upon them. They appeared to roam from point to point, seeking an outlet; but finding none, they one after another succumbed to their altered conditions and died. But other fish not only live but thrive well, apparently having no consciousness of any altered circumstances in their existence. These, from a constant and close inspection, will, I hope, furnish us with opportunities of recording notes of their habits and ways that cannot be obtained under less favourable conditions.

The beautiful Blue Wrasse (*Labrus mixtus*) has already given us an instance that is important in the history of its life, in the decided preference it exhibits in sexual selection. It was not until it had been observed in confinement that the Blue Wrasse and the Spotted Wrasse were known to be one and the same species. The male is very much more rare than the female, and is probably supposed to be more rare than it is, from the fact that those that have been confined in the pond at Plymouth appear to be losing the distinguishing colours and assuming that of the female as the summer time is passing on, so that there is much reason to believe that the beautiful deep-blue colour only exists, or at least is much more intense, during the pairing or breeding time.

During this period the male has been seen to select its special favourite out of a considerable number of females congregated in the pond, and faithfully accompany her as she swam about from place to place. In accordance with this same observation, Mr. Alford Lloyd, of the Crystal-Palace Aquarium, informed me that when at Hamburg he had noticed this peculiarity, and first drew my attention to it. He said that having a very handsome specimen of the Blue Wrasse, he placed him into a tank of water alone: instead of conducting himself like an orderly fish and swimming quietly, he for some time swam eagerly about in search of change; but not finding it, he took the unusual freak of jumping out of the tank; this he did two or three times. Fearing to lose him, it was determined to put another in with him; and a female specimen was selected. This appeared to have no very favourable success, for the Blue Wrasse most ungallantly chased her about, and tried to drive her from his presence. Another female was selected, with the same result. It was then determined to place the original specimen into a tank in which there were several swimming peacefully about, among which were many unselected females. Immediately the transfer was made, the animal swam amongst the forlorn group and fixed on one, by no means the handsomest of her sex, and selected her as his mate. With this one he was returned to his own tank; and here he conducted himself in a peaceful manner, never attempting again to jump out of the tank in which he was confined.

I have also to record the capture of a specimen of the Bogue (*Sparus boops*, L.), 11½ inches long; when it was brought to me it was in a very beautiful state of preservation. Of this species there have been but two or three specimens taken, and these scarcely so fine as the specimen now recorded. It was taken in a trawling-net, and brought in alive, but did not survive its capture. The specimen is preserved in the collection of the Museum of the Plymouth Institution.

Mr. Brooking Rowe informs me that in July last a specimen of the German or Long-finned Tunny (*Orcynus alalonga*) was taken in the Laira estuary,

near Plymouth. It was 9 feet long; the tail, from tip to tip, was 2 feet 11 inches wide; the girth 5 feet 11 inches: it weighed 800 lbs. This is, I believe, only the fourth example mentioned as having occurred in Great Britain.

On the 6th of September last I had brought to me a small fish (living) about three quarters of an inch long, of a purple-black colour, with the exception of the caudal, posterior dorsal, and postanal fins; these were so transparent as not to be visible without extreme care while the animal was in the water. The head was large, with the upper jaw slightly protruding over the lower. The head was elevated between the eyes, and three sharp spines were present on the postero-lateral margin, just above the gill-covers; a row of small spines were visible on each side of the posterior half of the body, and three large spines are implanted at the lower base of each lateral fin; but the most striking peculiarity of the animal exists in the large size of the fins themselves, particularly the laterals. There are four, two upon each side; they are narrow at the base, where they are connected with the animal, from which point they gradually, but rapidly, increase in width and length, until the latter is about one third of the length of the animal, and the former more than equal to its depth.

An examination of its details with that of known species has led me to the conclusion that it is a young specimen of the Grey Gurnard (*Trigla gurnardus*).

Crustacea.

Among the Crustacea I have as yet but little to report, some observations on the earlier development of the *Homarus* having been interfered with by the loss or robbery of some specimens that I had retained in special crab-pots some fathoms under water. This has deferred the opportunity until another season.

There are, however, two subjects of interest that might be here alluded to. The first is the decrease that is perceptible in the numbers of the edible species of Crustacea. This is the more apparent in the littoral than in the deep-sea forms, and is likely to be more felt with the rapidly increasing prices of articles of consumption. The circumstance no doubt arises from the custom of destroying the females as well as the males at all seasons of the year, and of the preference given for culinary purposes to the female lobster (*Homarus marinus*) when heavy with spawn. The increased value of the animal makes it eagerly sought after by fishermen.

But there is not even this excuse for the capture of the female crab (*Cancer pagurus*). The marketable value, as compared with the male, is at least one fifth; this arises from the smaller size of the animal as a whole, and of their claws in particular. But they are captured in greater numbers, and are consequently wantonly destroyed, being frequently hawked about the streets for a very few pence apiece. It appears to me that there could scarcely be any hardship inflicted, even temporarily, upon "shell-fishermen" if they were interdicted from taking the female lobster during the spawning-season, that is, from February until May, and that of the common crab at all.

I am aware that this suggestion is open to the remark that the lobster and the crab are so prolific that the number of ova that each hatch in a season is in the former several hundred thousand, and in the latter more than a million at a time, and that these very large numbers would within a short period soon stock all the bays of our coast. To this I would reply, that in all those forms of life where the ova are most abundant, the development of

that species is least in proportional quantity. This is true of crustacean life as well as that of other forms; and I think it worthy of consideration, particularly by those who, as a crucial test in the theory of evolution, demand the exposition of a series of successional forms of life; they should remember that of the lobster, common as it is around our coasts and in our markets, there is not a fisherman or observant naturalist who has yet seen that stage in its life which unites the animal as we know it with that which we have seen it when it quits the egg; that is, no one has seen or knows any thing about the animal between the time when it is half an inch and the time when it is four inches in length. That which is true of the lobster, is likewise true of all the higher forms of Crustacea, excepting only that of the common littoral or shore-crab (*Carcinus mœnas*).

The second circumstance that I wish to notice is one that has been elucidated by observation in the aquarium. I have several times observed that a specimen of *Pagurus*, or soldier crab, will seize hold of the shell in which another, generally smaller, specimen of the same species is dwelling. I supposed that the larger animal was covetous of the shell in which the smaller dwelt. I have seen them, as I thought, endeavour to take possession of such occupied shell, until their soft and tender body received such a pinch from the previous possessor as compelled them hastily to retrace their steps.

Mr. Alford Lloyd has written in my note-book the following sentence:—"In the spring of the year, in the Hamburg Aquarium, I have seen the male of this crab take hold of the shell in which a female is contained, and carry her about for weeks together, grasping the thin edge of her shell (as of a *Buccinum*); and when the female is fed the male does not take away the food, as he would if a male were so fed in his vicinity."

I would here like to state that the preservation of Crustacea by keeping them in glycerine for a few days, and then drying them, will be found to be a very superior plan to that of spreading them out without any preparation. I have specimens that have been treated two or three years with glycerine that are as flexible as a fresh crab. It will be better of course that as much of the soft parts should be removed as possible. I have also been trying, and I think with success, to preserve fish in the same way. A specimen of the Bogue (*Sparus boops*, L.), taken more than two months ago, is as fresh in colour and as flexible as when captured, excepting the eye, which was in a partially decomposed state when placed in the glycerine. I think, when further experiments have confirmed the fact, that with or without admixture with another medium, glycerine may afford a very valuable addition to the preservative agents of our museums.

Among the Mollusca we have to record the capture of many specimens of *Eledone* ——. This has generally been supposed to be a rare species on our coast; but we find that *Octopus vulgaris*, the supposed common species, is the more difficult to obtain. Both these appear to live well and happily in captivity; so also does *Sepia officinalis*.

Mr. Rogers, who has charge of the pond at Plymouth, and is a most active and zealous collector of marine animals, tells me that two specimens of this last-named cuttlefish were placed in the pond on the 8th of June, 1871. They continued doing well until the 24th, when they were seen to be *in copulâ*, head to head, arms interlaced, and remaining stationary, resting on the bottom for about twelve minutes, then separating. On the 26th the male was killed by a dog, which seized it when in shallow water. These creatures were rarely seen far apart, usually following each other in every

direction, swimming with equal ease either backward or forward; they were never seen to feed, but always appeared to be in search of food, after the manner of the Wrasses, moving slowly round the sides of the pond and rocks, thrusting their heads into holes and crevices: when disturbed, they darted through the water with great swiftness.

The female died on the 6th of July, and on being opened was found to be in very good condition, and to contain a large quantity of ova.

I have been taking steps to have within the cave behind the pond a case with a glass front so constructed as to enable us to watch the habits of animals with the greatest care. The water in this pond is several degrees lower in temperature than that in the tanks of the Crystal-Palace Aquarium, a circumstance that will enable us to study marine life under still more natural conditions. I believe that students of marine life will find this pond to be a valuable instrument for the carrying out of prolonged researches in the examination of structure or the development of animals; and they will find in the keeper an ever willing and obliging assistant and cooperator.

I cannot close this Report without expressing great regret at the loss of our old friend and fellow naturalist, Jonathan Couch, of Polperro. He was a close observer and zealous lover of nature, and only wanted the advantages of a less secluded life to have placed him among the foremost of our naturalists. He died at a ripe old age, and, I am sorry to say, has left a widow and three children in the greatest straits of poverty, to assist whom would be a kind and generous testimony to a long and well-spent life.

Preliminary Report of the Committee appointed to construct and print Catalogues of Spectral Rays arranged upon a scale of Wave-numbers, —the Committee consisting of* Dr. Huggins, Mr. Lockyer, Professor Reynolds, Professor Swan, and Mr. Stoney (Reporter).

The reference of spectral lines to a standard scale of wave-numbers, instead of to a scale of the wave-lengths in air of a given pressure and temperature, or to any of the other scales in use, has very marked advantages. The scale of wave-numbers furnishes *to the theoretical inquirer* the ratios between wave-lengths, which are what he chiefly wants, in the simplest and most conspicuous form, since a series of rays of which the wave-lengths are in geometrical proportion will be represented by equidistant lines upon the map. No person who has not encountered the task can conceive how tedious it is to carry on a theoretical investigation with any other scale. And *to the observer* the scale of wave-numbers offers the advantages which have been well stated by Professor C. A. Young in the following words:—"An accurate chart of the solar spectrum on which the lines should be mapped according to 'inverse wave-length,' proposed by Captain Herschel himself, I believe, as well as by Mr. Stoney and others, would sufficiently resemble the spectrum seen in a spectroscope to be equally convenient in the observatory with that of Kirchhoff, and would be free from the reproach of arbitrariness and irregularity in its scale. Such a chart would be most gladly welcomed by all spectroscopists, and would immediately supersede those of Kirchhoff and Ångström." (See a letter from Professor Young in 'Nature' of the 6th June, 1872.)

* The term *wave-numbers* appears preferable to the equivalent term "inverse wave-lengths" which has been hitherto used.

Accordingly, your Committee decided on reducing to wave-numbers all the wave-lengths, whether of solar lines or of the rays of incandescent vapours, which have been determined with sufficient precision. Mr. Charles E. Burton has offered his services gratuitously for making the necessary reductions, and has made considerable progress with the solar spectrum, the greater part of which is now nearly ready for the press.

A specimen of the catalogue of solar lines is appended to this Report, containing the lines from E to b. It is intended that this catalogue shall contain in a compact form all the most useful information that is available, viz.:—References to the position of each line on Kirchhoff's and Ångström's maps, details of the process by which the standard wave-numbers have been deduced, and indications of the intensity, width, and origin of each ray wherever these have been determined*. The rays will, moreover, be bracketed into the groups which strike the eye in looking at the spectrum, and a number will be assigned to each group which will sufficiently indicate its position on the standard scale.

Your Committee have as yet only incurred an expenditure of £4 for books, maps, and preliminary printing. This leaves a balance of £16 in their hands out of the grant of £20 placed at their disposal last year.

It is estimated that the two catalogues which the Committee propose to publish (the Catalogue of the Principal Lines of the Solar Spectrum, and the Catalogue of Rays of Incandescent Vapours) will cost about £60. This does not include the cost of the charts, which ought to accompany the catalogues in order to render them complete. The charts would increase the entire sum to be expended, including the grant already made, to about £120; but a portion of this sum would return to the Association in the form of the proceeds from the sale of the catalogues and charts.

Your Committee think that they could render the second catalogue more perfect if they were in a position to employ a competent person to revise and extend the determinations of the rays of incandescent vapours; and they therefore suggest that this revision be made a part of their functions, and that an addition of £50 be made to the grant for this purpose. This would increase the sum to be granted this year to £150.

The Committee accordingly recommend that they be reappointed, and that this sum be placed at their disposal, in addition to the balance at present in their hands.

Appendix.

Specimen of a Catalogue of the Principal Dark Rays of the visible part of the Solar Spectrum, containing all the Rays registered by Kirchhoff and Ångström, arranged on a scale of Standard Wave-Numbers. (The Specimen contains the Rays from E to b).

Column 1 gives the position on the Arbitrary Scale attached to Kirchhoff's maps.

Column 2 reproduces the wave-lengths in tenth metres as determined by Ångström, after applying to the numbers of Ångström's list the small corrections which he indicates at p. 29 of his memoir, "Le Spectre Normal du Soleil." The wave-lengths of this list are wave-lengths in air of 760 millims. pressure at Upsala, and 16° C. temperature.

Column 3 contains the reciprocals of the numbers of Column 2, each mul-

* Mr. Burton intends to revise the more refrangible part of the spectrum, and to supply the intensities and widths of the lines of this portion, which was not included in Kirchhoff's investigation.

tiplied by 10^7. Each number in this column is accordingly the number of times that the corresponding wave-length in air goes into one millimetre.

Column 4 contains the correction for the dispersion of air of 760 millims. pressure and 16° temperature, deduced from Ketteler's observations (see Phil. Mag. for 1866, vol. xxxii. p. 336).

Column 5 contains the Standard Wave-numbers, *i. e.* the number of waves per millimetre *in vacuo*.

Column 6 indicates the intensity and width of each ray as determined by Kirchhoff, 6 being the most intense, and g very wide, viz. about 0·15 of one degree on the Scale of Standard Wave-numbers.

Column 7 enumerates the substances which have been found to emit bright rays coincident with solar lines, and contains some other remarks.

Column 8. In the last column the rays are bracketed into the groups which strike the eye in looking at the spectrum, and to each group is assigned a number which sufficiently indicates its position upon the Standard Scale.

Position on Kirchhoff's Arbitrary Scale.	Ångstrom's wave-lengths in air.	Number of waves per millimetre in air.	Correction for the dispersion of the air.	STANDARD WAVE-NUMBERS.	Intensity and Width.	Origin &c.	Groups of Rays.
1515·5	5275·19	1895·67	0·53	**1895**·14	4 d		Group **1898** (Group E) Very strong.
16·5	5274·42	95·94		**1895**·41	4 c		
19·0	5272·67	96·57		**1896**·04	4 d	Fe.	
22·7	5269·59	97·68		**1897**·15	6 c	**E**₁ Fe and Ca.	
23·7	5268·67	98·01		**1897**·48	6 c	**E**₂ Fe.	
25·0	5267·39	98·47		**1897**·94	1 b	Co.	
27·7	5265·94	99·00		**1898**·47	5 c	Fe } Between these two rays, a ray of cobalt.	
28·7	5264·68	99·45		**1898**·92	5 c	Ca }	
30·2	5263·51	99·87		**1899**·34	4 c	Ca.	
31·2	5262·60	1900·20		**1899**·67	4 c	Fe	
32·5 33·1	5261·11	00·74		**1900**·21	4 b 4 b	Ca Ca } double.	
	5259·78	01·22		**1900**·69			
41·4 41·9	5254·21	03·23		**1902**·70	1 g 3 b	Fe and Mn. A winged ray.	Group **1904**. Faint.
43·7	5252·60	03·82		**1903**·29	2 a	Fe.	
45·5	5251·15	04·34	0·53	**1903**·81	2 a	Fe	
47·2	5249·81	04·83	0·535	**1904**·30	3 a	Fe.	
47·7	5248·60	05·72	0·54	**1904**·73	2 a		
51·0 51·6	5246·43	06·06		**1905**·52	2 a 2 a	Fe double.	
55·6	5242·86	07·36		**1906**·82	2 a	Fe.	
57·3	5241·67	07·79		**1907**·25	3 a	Fe.	
61·0	5239·16	08·70		**1908**·16	1 a	Fe.	
64·2	5236·44	09·69		**1909**·15	1 a		
66·5	5234·52	10·39		**1909**·85	2 b	Co.	Group **1912**. Strong.
67·5	5233·72	10·69		**1910**·15	2 b	Mn.	
69·6	5232·24	11·23		**1910**·69	5 c	Fe.	
73·5	5229·14	12·36		**1911**·82	5 a	Fe.	
75·4	5227·63	12·91		**1912**·37	1 b		
77·2 77·6	5226·38	13·37		**1912**·83	5 c 3 c	Fe and Ti. According to Ångstrom a *triple* ray, very strong.	
79·4 80·1	5224·42	14·09		**1913**·55	2 a 2 a	Ti Ti } double.	

Position on Kirchhoff's Arbitrary Scale.	Ångstrom's wave-lengths in air.	Number of waves per millimetre in air.	Correction for the dispersion of the air.	STANDARD WAVE-NUMBERS.	Intensity and Width.	Origin &c.	Groups of Rays.
1588·3	5217·28	1916·71		1916·17	1 g	Cu.	Group **1917**. Faint.
89·1	5216·64	16·94		1916·40	3 b	Fe.	
90·7	5215·64	17·31		1916·77	3 b	Fe.	
92·3	5214·50	17·73		1917·19	3 b	Fe.	
98·9	5209·59	19·54		1919·00	2 b	Ti.	Group **1921** (The Chromium Group). Strong.
1601·4 01·7	5207·78	20·20		1919·66	6 b 3 d	Fe and Cr. Winged ray.	
04·4	5205·37	21·09		1920·55	5 b	Cr.	
06·4	5203·88	21·64		1921·10	5 b	Fe and Cr.	
09·2	5201·69	22·45		1921·91	5 b	Fe.	
11·3	5199·89	23·12		1922·58	1 c		
13·9	5198·08	23·79		1923·25	3 b	Fe.	Group **1924**. Faint.
15·6	5197·19	24·12		1923·58	2 b		
16·6 17·4	5195·33	24·81		1924·27	1 b 2 b	Mn double.	
18·2 18·9	5194·24	25·21		1924·67	3 b 4 b	Fe double.	
21·5	——	——		1925·36	1 b	Ti.	Group **1926**. Strong.
22·3	5191·80	26·11		1925·57	5 c	Fe.	
23·4	5190·68	26·33		1925·99	5 b	Fe.	
27·2	5188·33	27·40		1926·86	5 b	Ca.	
28·2	5187·49	27·71		1927·17	1 b	Ti.	
31·5	5185·24	28·55		1928·01	1 b	Fe.	Group **1932** (The Great Magnesium Group).
33·5 34·1 34·7	5183·10	29·35		1928·81	4 g 6 g 4 g	b_1. Mg. Winged ray.	
——	5182·75	29·48		1928·94	---		
38·7	5179·66	30·63		1930·09	1 b	Fe.	
——	5178·27	31·15		1930·61	---		
42·1	5176·52	31·80		1931·26	1 b		
43·0	5175·73	32·09		1931·55	1 b	Ni.	
47·3	——	——		1932·53	5 a		
48·4 48·8 49·2	5172·16	33·43		1932·89	4 e 6 f 4 e	b_2 Mg. Winged ray.	
50·3	5171·20	33·79		1933·25	6 b	Fe.	
53·7 54·0	5168·48	34·80		1934·26	6 b 4 e	b_3. Fe Ni. Winged ray	
55·6 55·9	5166·88	35·40		1934·86	6 e 4 d	b_4. Fe Mg. Winged ray.	
57·1	5165·88	35·78		1935·24	5 b	Fe.	
From 58·3 to 59·4	5164·73	36·21		1935·67	2 b 1	Fe. Wing very broad.	

Third Report of the Committee appointed to consider and report on the various Plans proposed for Legislating on the subject of Steam-Boiler Explosions with a view to their Prevention,—the Committee consisting of Sir WILLIAM FAIRBAIRN, *Bart., C.E., F.R.S., &c.,* JOHN PENN, *C.E., F.R.S.,* FREDERICK J. BRAMWELL, *C.E.,* HUGH MASON, SAMUEL RIGBY, THOMAS SCHOFIELD, CHARLES F. BEYER, *C.E.,* THOMAS WEBSTER, *Q.C.,* EDWARD EASTON, *C.E., and* LAVINGTON E. FLETCHER, *C.E.*

WHEN the Committee presented their last Report on the subject of "Steam-Boiler Legislation" to the Meeting of the British Association held at Edinburgh, it was fully expected that the measure, having for its object the prevention of Steam-Boiler Explosions, which was then before Parliament, having been introduced by John Hick, Esq., Member for Bolton, as the result of the inquiry by the Parliamentary Committee which sat upon this subject during the Sessions of 1870–71—it was fully expected that this measure would by this time not only have passed through Parliament, but also have been in active operation, so that some practical results might have been arrived at. Such, however, has not proved to be the case. The Bill, though read a first time in the House of Commons late in the Session of 1871, and reintroduced this year as early as the 7th of March, has not yet passed a second reading, having been postponed from time to time. It was thought better to wait the maturity of Mr. Hick's Bill before assembling the Committee for consultation; but this course, though considered advisable, has, owing to the delay just referred to in the progress of the Bill, prevented the Committee completing their report for presentation at this Meeting of the British Association. Under these circumstances they request an extension of time, and suggest their reappointment for another year, when they hope to complete the task assigned them.

Report of the Committee, consisting of JAMES GLAISHER, *F.R.S., of the Royal Observatory, Greenwich,* ROBERT P. GREG, *F.R.S.,* ALEXANDER S. HERSCHEL, *F.R.A.S., and* CHARLES BROOKE, *F.R.S., Secretary to the Meteorological Society, on Observations of Luminous Meteors,* 1871–72; *drawn up by* ALEXANDER S. HERSCHEL, *F.R.A.S.*

AMONG the objects whose special promotion it was suggested in the last Report that the Committee would undertake by combined observations during the past year, the attention of observers at several stations in Scotland and England well used to accurate and systematic registry of shooting-stars was, as in former years, frequently not unsuccessfully directed, at the request of the Committee, towards recording the appearances of shooting-stars visible on the annually recurring meteoric dates in August, October, November, December, January, and April.

The August meteors were somewhat more brightly visible last year than commonly, on the two successive nights of the 10th and 11th of August, and the clearness and darkness of the sky enabled a more than ordinarily large number of meteors to be carefully observed. From a long list of meteor-paths

recorded both at the Royal Observatory, Greenwich, and by the observers for the British Association, the heights of twenty meteors of the shower visible on the different nights of its reappearance were calculated, and several other meteors were identified as having been doubly observed whose real paths have not yet been computed. The position of the radiant-point of the shower* was found to be, as recently pointed out by Mr. Hind in a letter in 'The Times' of August 8th, more northerly than hitherto, at a point in R. A. 35°, N. Decl. 59°, three or four degrees north-westwards from χ Persei towards ι Cassiopeiæ.

A few meteors of the October shower were visible on the 19th of October last; but the sky being overcast, with stormy weather, on other nights of the shower, the time and rate of frequency of their fall at the maximum intensity of the shower could not be ascertained; and from the few recorded meteor-tracks only a roughly approximate position of its radiant-point was obtained.

The condition of the sky was generally little more favourable for observations in November and December than in October; but on the morning of the 13th of November a clear view of the Leonids was obtained both at Stonyhurst College and at the Royal Observatory, Greenwich, while on another following morning, that of the 15th of November, they were also well seen by Professor Herschel at Newcastle-upon-Tyne; and their abundance on the latter date was considerably greater than that of the unconformable meteors from all parts which appeared at the same time with them. The distribution of the November meteor-group along the ring which forms its orbit being at present unknown, the watch for the return of the Leonids this year will be renewed for the purpose of comparative observations of their greatest rate of frequency in successive years. No accordant observations of single meteors appear to have been recorded either during the October or November star-showers.

At most of the corresponding places a clear view of the December shooting-stars was obtained on the night of the 12th, while the sky was everywhere completely overcast on the 13th. Meteors appeared at the rate of ten or twelve per hour for one observer from the direction of Gemini; and the position of the radiant-point in this constellation could be pretty correctly ascertained by the meteor-tracks recorded on the night when they were principally observed. This appears, as in former years, to have been near θ Geminorum.

On the night of the 2nd of January a favourable state of the sky permitted a considerable display of the January meteors to be seen at several of the corresponding stations, and to be simultaneously recorded at the Royal Observatory, Greenwich. The star-shower continued with about equal brightness until daybreak on the morning of the 3rd of January; but a cloudy sky on the night of the 3rd everywhere prevented the close or a continuation of the shower from being seen. In this and the December meteor observations several examples of doubly observed shooting-stars were found, of which, with those of some other similar observations contained in these descriptions of the meteor-showers of the past year, the heights will be immediately calculated. The radiant-point of the January star-shower appears not to have altered its place sensibly in the interval since its last principal appearance in England on the 2nd of January, 1864†.

The last meteoric shower of the past year which was successfully watched for by the observers was that of April 19th, 1872, when a few conspicuous meteors, radiating from the direction of Lyra, were recorded at nearly all the stations, and also at the Royal Observatory at Greenwich, and, under the direc-

* Which appears, from the few observations of the shower on the 9th and 10th inst. (August 1872), to have very nearly maintained the same position in the present year.

† See the volume of these Reports for 1864, p. 98.

tion of the Rev. R. Main, by Mr. Lucas at the Radcliffe Observatory at Oxford. The watch at the latter place was continued during the night of the 19–20th of April until the morning hours, and the Lyraïds continued to be more and more abundant until daybreak. The position of the radiant-point was close to that found in the former observations of 1864*. The prevalence of some other radiant-points of shooting-stars chiefly producing, it appears, bright meteors during the months of March, April, and May was discernible; and the heights of two bright meteors from different radiant-points that appeared on the night of the 19th of April will be approximately obtained from double and triple observations of their apparent paths which were then recorded.

The heights of some large meteors seen on other nights of the year have also been determined with some certainty from corresponding observations of them at distant places, of which a short description is given, with that of the principal observations from which they are derived. Large meteors have been seen in more than ordinary numbers during the past year; and the information respecting several of these meteors which has been received by the Committee is included in a general list in continuation of some former notes of meteors of the largest class. But two aërolites appear to have fallen during the years 1871–72; the first at Searsmont, in the United States, on the 21st of May, 1871, and the second in November, 1871, at Montereau, in France.

At the conclusion of the Report the contribution of some recent valuable additions to meteoric literature by the Italian astronomers and observers of shooting-stars, Prof. Schiaparelli and Signor Denza, in combination with a well-known representative of meteoric science in Germany, Dr. G. von Boguslawski, is briefly noticed and described; and in the last place a long list of radiant-points placed in comparison with each other in a single Table by Mr. Greg at the close of this Report, forms a complete comparative index † of the epochs and positions of all the meteoric showers included in the general lists hitherto published for the northern hemisphere.

Great improvements of this Table will, it cannot be doubted, be made by reducing the many meteor-tracks, of which, since the appearance of the last printed meteor-catalogue in these Reports, a large number of descriptions have been received. To enable them to accomplish this undertaking, the continuation of the Committee's operations, and of a grant to support them in executing charts and tracings, is earnestly recommended to the British Association. The watchfulness of observers on every fine night when favourable opportunities present themselves for recording the occasional appearances of shooting-stars, in order to contribute fresh materials for the same purpose, is once more appealed to, in addition to the nights of annual recurrence of meteor-showers, of which, as before, due notice will be regularly communicated to them by the Committee, and suitable means will be furnished to them to enable them to assist these objects by their observations, to which their attention will again be invited at the returns of the several meteoric epochs, as in former years.

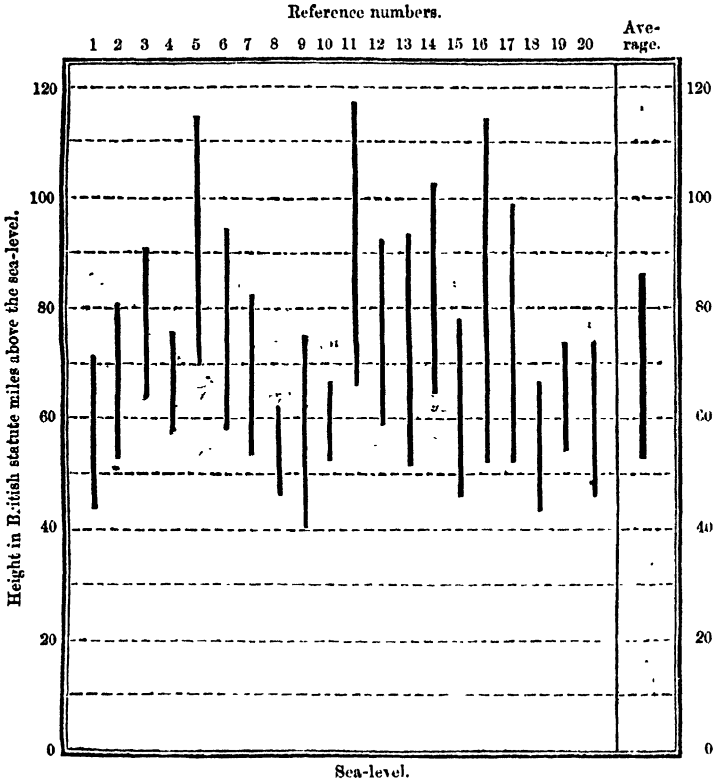
I. Meteors doubly observed.

Among the meteors observed during the simultaneous watch for the annual meteor-shower of August, December, January, and April, in 1871 and 1872, several accordant observations of individual meteors were found, enabling their real heights to be satisfactorily ascertained. A list of such accordances

* See the volume of these Reports for 1864, p. 98.

† An equally extensive list by Dr. J. F. Schmidt, of Athens (Astronomische Nachrichten, No. 1756, 1869), unknown to the Committee when the accompanying Table was compiled, is, for the present, omitted from its comparisons.

on the nights of the 10th and 11th of August, 1871, with the results obtained from them as computed by Professor Herschel, appears in the 'Quarterly Journal of the Meteorological Society' for November 1871, from which the annexed figure is copied, showing the real heights of first appearance and of



Real Heights of twenty Shooting-stars, doubly observed in England on the nights of the 9th to 12th of August, 1871, above the surface of the earth.

disappearance of twenty shooting-stars of last year's August shower, together with their average real height. On comparing together the actual horizontal distances from the observers at which their apparent points of disappearance had been accurately recorded, it appears that a circle 160 miles in diameter represented a field of view within which four fifths of all the terminations of the meteors' visible paths were seen and recorded by the observers, mapping their apparent courses at its centre; and that, on the average, three or four times as many accordances of observations are likely to be obtained by observers at stations separated from each other by distances of between forty and eighty miles, as at places either nearer to or more distant from each other than about these limits.

The average heights of the meteors thus observed above the earth's surface was 86 miles at first appearance, and 52·5 miles at disappearance; the average length of path 46 miles, and the average velocity of nine Perseïds contained in the list 51 miles per second. The difficulty of estimating exactly the small duration of their rapid flights, and a tendency, by aligning their apparent

courses with the brightest neighbouring fixed stars, to overstate rather than to underrate the apparent length of their visible flights, will perhaps account for the excessive real velocity of the Perseïds obtained in these results of the simultaneous observations. The velocity of a single meteor of the shower, as bright as Sirius (the first meteor shown in the diagram), unconformable to Perseus, and directed from the radiant-point in Pegasus, was somewhat more exactly obtained, both its apparent path and its duration being very carefully observed by Mr. Wood at Birmingham and Mr. Clark at York; whose observations were in excellent agreement. The real length of the path of this meteor was 38 miles, and its resulting real velocity was 19 miles per second.

On comparing together the observations of the shooting-stars recorded at Greenwich with those seen at the British-Association stations during the same August shower, several perfectly accordant observations were found on the night of the 11th; and but few satisfactory identifications of meteors doubly observed on the night of the 10th of August, excepting that of the brightest (at $10^h\ 51^m$ P.M., as noticed in the following descriptions of the shower), could be detected. The following list contains a general description of the various shooting-stars which appear to have been doubly observed at the Royal Observatory, Greenwich (and by the observers at other stations), on the night of the 11th of August, and on the other nights of simultaneous watch kept for the reappearance of the annual meteor-showers which have been visible during the past year.

A few double observations of shooting-stars are also contained in the accompanying list of bright meteors, and in the detailed accounts which will shortly be given of the observations of the meteoric showers. The meteor No. 7, whose real height is figured in the above diagram from observations at York, at Hawkhurst, and in London, was also seen at the Royal Observatory, Greenwich, and its apparent path was there recorded at $11^h\ 14^m\ 59^s$ P.M. on the 11th of August. The redetermination of the real height of this meteor by comparison of the new observation with the former ones, and the computation of the several meteor-heights to be derived from the additional observations contained in this Report, will afford interesting materials for future consideration.

The last meteor in the accompanying list, on the 19th of April last, will be seen to have been triply observed at York, Wisbeach, and Hawkhurst. The heights determined from the observations at the first two places are 66 miles at first appearance, and 41 miles at disappearance. But if the observation at Hawkhurst is correct, the meteor probably moved at an elevation of not more than 50 or 55 miles at first appearance and 30 or 35 miles at disappearance. From the former observations the length of its visible path was 90 miles; but in the latter case it would not exceed 70 miles; and if the observations at York and Hawkhurst only are employed, as affording the widest parallax, it would be somewhat less. The duration of its flight was probably underestimated at York at half a second, and overestimated at Wisbeach at 3 seconds. The average duration is $1\frac{3}{4}$ second, giving the probable velocity of the meteor not more than 40 miles per second; while the actual velocity of the Lyraïds, calculated from the astronomical theory of the great April meteor-group, is 30 miles per second. The recorded paths of this member of the shower diverged very exactly from a common radiant-point between π and θ Herculis, about 20° from the usually observed centre of divergence of the meteor-group in Lyra.

The estimated height of a bright meteor seen on the 31st of August last was also obtained from accordant observations of its apparent path at Ross

in Herefordshire and at Hawkhurst, as will shortly be noticed in its particular description. The confirmations of the astronomical theory of large meteors and shooting-stars, and the advance of our existing knowledge of the laws that regulate their courses, characteristic rates of motion and appearance, and

Shooting-stars doubly observed during the Annual

Date.	Hour.	Place of Observation.	Apparent Magnitude, as per Stars.	Colour.	Duration.	Position.
1871.	h m s					
Aug. 11	10 6 0	Hawkhurst	3rd mag.	....	Very swift ...	$\alpha=$ $\delta=$ From 315°+80° to 246 +65
11	10 6 53	Royal Observatory, Greenwich.	1st mag.	Bluish white .	0·7 second ...	From the direction of ϵ Cassiopeiæ, passed in direction of o Cygni.
11	10 11 0	Hawkhurst	1st mag.	....	....	$\alpha=$ $\delta=$ From 265°+62° to 217 +45
11	10 12 7	Royal Observatory, Greenwich.	2nd mag.	Bluish white .	1·0 second ...	From direction of γ Cygni shot across δ Sagittæ.
11	10 14 30	York..............	From 1st mag. to size of ♃.	Red	1·5 second ...	$\alpha=$ $\delta=$ From 326°+ 8° to 314·5−12
11	10 15 9	Royal Observatory, Greenwich.	Brighter than ♃...	Bluish white .	1·3 second ...	Passed about 3° above b Lyncis, from the direction of c Camelopardi.
11	11 0 30	Bolton, Cheshire	....	....	....	$\alpha=$ $\delta=$ From 294°+33° to 28 +25
11	11 0 48	Royal Observatory, Greenwich.	1st mag.	Bluish white .	0·7 second ...	From direction of ϵ Cassiopeiæ passed across δ Persei.
11	11 14 59	Ibid	Brighter than 1st-mag. *	Bluish white .	More than 1 second.	Across δ Ursæ Majoris to 12 Canum Venaticorum.
11	11 16 0	Regent's Park, London.	1st mag.	Blue...........	....	$\alpha=$ $\delta=$ From 180°+76° to 191 +51
11	11 16 0	Birmingham ...	Brighter than 1st-mag. *	Green	1·5 second ...	From 8°+36° to 240 +58
11	11 26 0	Ibid	Brighter than 1st-mag. *	....	1·0 second ...	From 350°+77° to 265 +71·5
11	11 26 23	Royal Observatory, Greenwich.	1st mag.	Yellowish.....	1 second	From ϵ Ursæ Majoris. Fell towards horizon.
11	11 34 0	Hawkhurst	= ♃	....	....	$\alpha=$ $\delta=$ From 350°+76° to 27 +60
11	11 35 45	Royal Observatory, Greenwich.	Brighter than 1st-mag. *	Bluish white .	1·5 second ...	From direction of κ Andromedæ passed about 1° to the right of β Andromedæ.

the dates of their greatest frequency, may be greatly assisted by the accounts of those who are favourably situated to observe them, even without the special accuracy which should yet always be aimed at in descriptions of these hitherto but partially investigated phenomena.

Meteoric Showers recorded in the years 1871 and 1872.

Length of Path.	Direction.	Appearance; Remarks.	Observer.
....	....	Left a slender streak	Miss Herschel.
10°	....	Left a streak	Wm. Marriott.
12°	....	Left a streak	Miss Herschel.
20°	....	No streak	T. Wright.
22°	....	Train not bright, but lasted 3½ seconds. [Identical with meteors at Hawkhurst, 10ʰ 14ᵐ, and London (Regent's Park), 10ʰ 15ᵐ.]	J. E. Clark.
15°	....	Left a fine streak, which remained visible for 3 seconds.	T. Wright & Wm. Marriott.
8°............	....	No particulars of appearance recorded.	R. P. Greg.
10°	....	Left a streak	Wm. Marriott.
20°	....	Left a fine streak	W. C. Nash.
....	....	Path imperfectly seen	T. Crumplen.
....	....	Left a long train on its course. (From ω Cephei to θ Draconis.)	W. H. Wood.
....	Radiant-point ε Cassiopeiæ ...	(From γ Cephei to ψ Draconis)...	Id.
10°	Fell towards the left at an inclination of 45°.	Left a fine streak	Wm. Marriott.
....	[From direction of Cygnus] ...	Left a broad fine streak. (From γ Cephei to just below ε Cassiopeiæ.)	Miss F. Herschel.
10°	[From direction of Cygnus] ...	Left a magnificent streak.	Wm. Marriott.

Date.	Hour.	Place of Observation.	Apparent Magnitude, as per Stars.	Colour.	Duration.	Position.
1871.	h m s					
Aug. 11	11 45 30	Hawkhurst	Brighter than ♃...	....	Slow speed ...	$\alpha=$ $\delta=$ From 23°+60° to 8 +62
11	11 46 56	Royal Observatory, Greenwich.	Brighter than 1st-mag. *	Greenish	1·3 second ...	From direction of ϕ Persei passed between μ and β Andromedæ to δ Andromedæ.
11	11 50 30	Hawkhurst	=3rd mag.	....	....	$\alpha=$ $\delta=$ From 340°+30° to 355 +42
11	11 51 10	Royal Observatory, Greenwich.	=1st mag.	Bluish white .	1 second	From α Pegasi in direction of γ Pegasi.
11	11 54 35	Ibid.	2nd mag.	Bluish white .	0·7 second ...	From α Draconis passed across θ Boötis.
11	11 55 0	Birmingham ...	3rd mag.	....	....	$\alpha=$ $\delta=$ From 332°+57° to 310 +36
11	12 3 0	Ibid.	3rd mag.	....	0·3 second ...	From 286°+20° to 278 + 6
11	12 4 4	Royal Observatory, Greenwich.	2nd mag.	Bluish white .	0·8 second ...	Passed between β and γ Herculis from the direction of ζ Herculis.
11	12 29 0	Hawkhurst	1st mag.	....	....	$\alpha=$ $\delta=$ From 323°+51° to 288 +20
11	12 29 25	Royal Observatory, Greenwich.	1st mag.	Bluish white .	1·2 second ...	From ϵ Cygni to γ Aquilæ.
Dec. 12	10 13 0	Tooting (near London).	Faint	....	....	$\alpha=$ $\delta=$ From 80°+9·5° to 71 +4·5
12	10 17 0 (time by watch, uncertain)	Hawkhurst	2nd mag.	Slow...........	....	From 75°+28° to 60 +23
1872.						
Jan. 2	11 4 30	Royal Observatory, Greenwich.	As bright as Jupiter	Bluish white .	1 second	From a point between α and β Ursæ Majoris passed in the direction of θ Aurigæ.
2	11 4 30	Eaton Square, London.	Brighter than 1st-mag. *	White	1·5 second ...	Disappeared at ½ (n, u) Lyncis. Course from γ Ursæ Majoris, beginning 6° short of that star.
2	11 5 30	Tooting, near London.	Large	White	....	$\alpha=$ $\delta=$ From 160°+55° to 135 +44

Length of Path.	Direction.	Appearance; Remarks.	Observer.
....	....	Brilliant nucleus and broad train. (From the left of δ Cassiopeiæ to beyond γ Cassiopeiæ.)	Miss F. Herschel.
10°	....	Left a splendid train	Wm. Marriott.
....	[From Pegasus]	Left no streak. (From η Pegasi to below ι, κ Andromedæ.)	Miss F. Herschel.
....	[Radiant in Pegasus]	Left a streak	Wm. Marriott.
10°	....	Left a streak	W. C. Nash.
....	....	(From head stars of Cepheus to κ Andromedæ.)	W. H. Wood.
....	....	From ½ (β Cygni, ε Aquilæ) to ε Aquilæ, and 10° beyond that star.	Id.
10°	....	Left a streak	W. C. Nash.
30°	....	Left a streak for ½ second. (Along the axis of Cygnus, and just south of it, as mapped.)	Miss Herschel.
....	....	Left a very fine streak	W. C. Nash.
7°	....	Position probably correct within ½° each way.	H. W. Jackson.
....	....	Left no streak. (From ½ (β, η) Tauri shot to a little below the Pleiades, disappearing some degrees before reaching them.)	Miss J. Herschel.
15°	....	Left a streak	Wm. Marriott.
20°	....	Left no streak........................	A. S. Herschel.
....	....	Left a streak. Position, as mapped, fairly well observed. (From a little south of β to a little south of κ Ursæ Majoris).	H. W. Jackson.

Date.	Hour.	Place of Observation.	Apparent Magnitude, as per Stars.	Colour.	Duration.	Position.
1872. Jan. 2	h m s 11 29 0	Hawkhurst	=Sirius	....	....	From about γ Cassiopeiæ towards α, β Arietis.
2	11 31 0	Eaton Square, London.	Brighter than 1st-mag. *	White	2 seconds......	From ⅓ (α, β) Aurigæ to λ Tauri.
2	11 33 0	Ibid	3rd mag.	White	1·4 second ...	From 130°+6·5° to 114 −6
2	11 33 0	Hawkhurst	=Castor	....	....	From 115°+29° to 91 + 4
2	11 54 0	Ibid	1st mag.	....	....	From B Camelopardi past α Persei, and past the Pleiades.
2	11 54 30	Eaton Square, London.	=Sirius	White, then orange.	2 seconds......	α= δ= From 96°+44° to 80 +10
Apr. 19	11 26 0	Wisbeach, Cambridgeshire.	1st mag.	Yellow	3 seconds......	α= δ= From 232°+73° to 107 +63
19	11 27 30	Hawkhurst	1st mag.	....	....	From 45°+56° to 50 +50
19	11 28 0	York..............	=Sirius	White	0·5 second ...	From 228·5°+29° to 203 +12

II. Large Meteors.

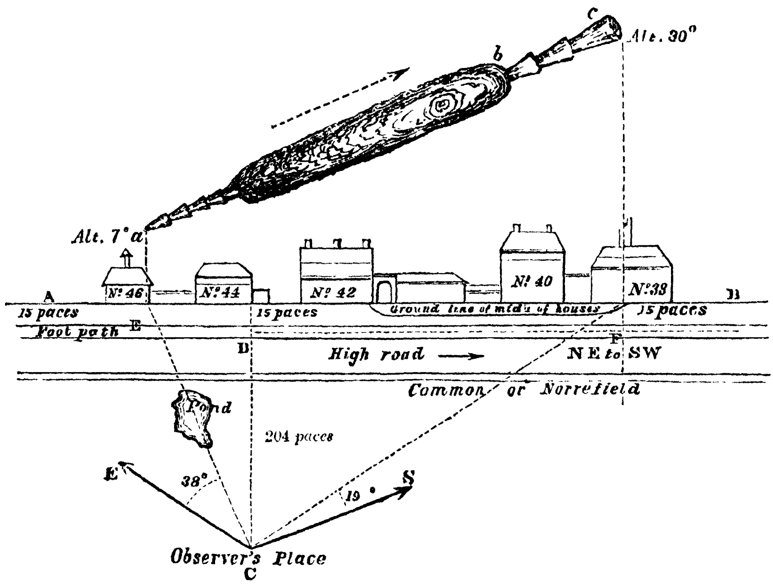
In addition to the occurrences of this kind of whose appearance accounts were received by the Committee since their last Report, the following list describes some conspicuous meteors of which no particulars were contained in previous Reports :—

1. 1851, July 30, 8^h 10^m P.M. (local time).—Two days after the total eclipse of the sun in the north of Europe in that year, a large fireball was seen in Denmark and on the coasts of the Baltic, in bright evening light; and it was described in many of the contemporary local newspapers. The

Length of Path.	Direction.	Appearance; Remarks.	Observer.
....	....	Brilliant; left a slight streak......	Miss M. R. Herschel.
....	....	Brightest in the last half of its course.	A. S. Herschel.
18°	....	Left no streak. (From middle of Hydra's head to 3° above n Monocerotis.)	Id.
About 25° ...	....	Left no streak. (Commenced near β Geminorum. Course three fourths of the way to a point 2° or 3° under Orion's belt.)	Miss F. Herschel.
....	....	Brilliant, and pear-shaped at last; left a long streak.	Miss J. Herschel and Miss M. R. Herschel.
....	Turned sharply in its course at a point 1° E. of ζ Tauri, with a very slight deflection.	Brightest in first half of its course, then fainter and redder to disappearance. Left a streak on its whole course for half a second.	A. S. Herschel.
40°	Lyraid	Left a streak on its course for 5 seconds. Appearance of the meteor at the third second of its flight (there appeared to be a sort of vibratory motion in the train).	S. H. Miller.
7° or 8°	Lyraid	Parallel to and just above γ, α Persei nearly from ϵ Cassiopeiæ.	Miss M. R. Herschel.
22°	Lyraïd	Motion noticeably rapid.	J. E. Clark.

following distinct account, and accurate drawing of the phenomenon, from the 'Transactions of the Royal Danish Academy of Sciences,' for 1869, show it to have been one of large size, perhaps aërolitic; and may afford a useful comparison with the descriptions of other equally remarkable meteors which will, perhaps, be known to have occurred on the same date of the year. Observation of the meteor:—Soon after sunset, in an almost cloudless blue sky, the first of four smoke-like triangles (at the point a in the figure) was observed to be formed, and the other cloud triangles were developed in succession, in about five seconds. In the place of the fifth, and in a continuation of the same line, an irregular column of smoke began to extend

itself, with much apparent commotion in the direction of the meteor's flight. In the first quarter of its length no light appeared in it; but in the second



Apparent course and appearance of a large Meteor seen at Copenhagen 1851, July 30, evening, by P. J. Winstrup.

and third it seemed to be mixed with flame of rapidly increasing brightness; and in the last third part of this portion of the meteor's flight, its nucleus was plainly visible, of intense whiteness and brilliancy at the centre, and surrounded with duller red light towards the border, which was of the same width as the smoke-wreath. It became extinguished at *b*, and from this point to *c* three more small cloud triangles, like those first formed, were added in quick succession to its length. The earlier portions of the smoke-wreath had by this time entirely disappeared, the meteor taking not more than three or four seconds to produce the cloud column, which was also the time taken by this part of the smoke-wreath and by each of the cloud triangles to disappear; so that the whole duration of visibility of the phenomenon was about fifteen seconds. Immediately after its disappearance, the blue sky at that place remained as clear and as bright as it had been before the meteor's passage. The cloud-substance of the triangles first formed was bluish white, like the smoke of gunpowder, while that in the upper part of the smoke-column became quite dark as it disappeared. By marking the first and last points of the meteor's course (*a*, *c*) with reference to the houses of a neighbouring street, and pacing their distance from his point of view, the apparent path of the meteor, as it was thus observed by Mr. Winstrup, appears to have been ascertained as follows:—

Point of commencement, *a*, altitude 7°, 52° east from south.
Point of disappearance, *c*, altitude 30°, 19° east from south.
Apparent length of the meteor's course, *a c*, about 42°.
Inclination of its apparent course to the horizon, about 38°.

2. In the 'Standard' of September 15, 1869, Mr. F. P. Bullock describes a remarkably bright meteor, which he saw at Cheltenham, at 10^h 8^m P.M., on the 12th of that month, passing rapidly, and with an extraordinary long course, over a complete quarter of the sky.

3. The following observations of rather bright meteors were communicated, with some of lesser magnitude noted during previous years, by Mr. J. E. Clark:—

1869, September 20, 6^h 46^m P.M.—A meteor about $\frac{1}{6}$ of the apparent size of the moon was seen by Mr. A. K. Brown, Mr. S. P. Thomson, and by other observers, at Denbydale, near Huddersfield, of pale yellow light, apparently not much stronger than that of Saturn, and changing to red. It fell about 15° in $2\frac{1}{2}$ seconds, nearly vertically, to a point about 15° above the east horizon, followed by a streak or tail of sparks, which became redder, like the nucleus, towards the end of its course.

1869, December 21, 8^h 15^m P.M.—Near Leominster, Mr. J. E. Southall observed a meteor of yellow colour, and of about the greatest brilliancy of the planet Venus, descending vertically $12\frac{1}{2}$° in half a second from a point in R. A. 97°, S. Decl. 7°, to R. A. 86°, S. Decl. 18°. The meteor was visible through light clouds, which obscured the view of any streak or sparks which may have accompanied it in its course.

4. At a meeting of the Natural History and Philosophical Society of Derry, in Ireland, on March 4, 1870, Mr. William Harte described some observations of a remarkable meteor which passed over Donegal on the night of the 27th of December 1869.

5. 1870, July 25, evening.—Soon after dark, a brilliant meteor was observed in Kent and at other places near the English Channel. At Dover it was seen to rise almost perpendicularly from the sea horizon in the east, increasing in splendour until it disappeared overhead. The first effect of its very striking and unusual upward course was to produce an irresistible impression that it was a signal rocket or other artificial light fired from some distant vessel on the sea. Some current descriptions of this fireball, which appeared in the daily journals at the time, have unfortunately escaped the notice of the Committee.

6. On the 16th of October, 1870, descriptions of two bright meteors received by the Committee appear to indicate some close connexion from their resemblance, although, from their recorded positions and from a slight interval between their times of appearance, they appear to be distinct. The first, which appeared to Mr. J. E. Clark and Mr. S. Giles, at York, at 8^h 25^m P.M., of red colour, increasing from the apparent brightness of a fourth-magnitude star to that of Venus, described a short course of 8° or 9° in three or four seconds, from a point in R. A. 22°, N. Decl. 20°, to R. A. 34°, N. Decl. 16°, leaving a few sparks, but no visible streak upon its course. At 8^h 28^m P.M., on the same evening, a meteor brighter than a first-magnitude star, and in every other respect of perfectly similar description with that observed at York, was seen by Mr. William Marriott, at Greenwich, describing, in the same time, an apparent course of the same length, in the northern sky, from the star ζ towards the star α in Draco. The meteor seen at York appeared in the south-east, at such a considerable distance from the direction indicated by the Greenwich observations as to admit of no possible consideration of their identity by the supposition of ordinary errors of observation. But the remarkable resemblance of their descriptions and their nearly simultaneous appearance, if not attributable to the earth's passage at the time through a common meteor-system, is yet a very similar occurrence

to the pairs and groups of meteors which are sometimes observed to appear in very brief succession in ordinary star-showers. The radiant-point of the pair, if these meteors might be so regarded, is between the constellations Cygnus and Vulpecula. But from their close vicinity, respectively, to the radiants R_3 and BG_6, in Musca, and in the neighbourhood of Draco, which first present themselves about the middle of October, it appears more probable that their remarkably foreshortened courses may be clearly individualized as distinct, and that they were evidently members, respectively, of those well-marked, and widely separated showers. A similar instance of coincidence, but apparently without real connexion, will shortly be noticed in a future page.

7. Another bright meteor, from one of the latter radiant-points, R_3, was recorded by Mr. Wood, at Birmingham, at $10^h\ 7^m$ P.M. on the 1st of November 1870; brighter than Sirius, white, and moving for two seconds in a short course close to the apparent place of the last meteor seen at York, from R. A. 27°, N. Decl. 21°, to γ Arietis. At $10^h\ 27^m$ a second-magnitude meteor, with a very short course, passed, leaving a streak across the Pleiades, proceeding from the same radiant-point, from which a few other meteors, noticed by Mr. Wood on that night, were also directed. In a note to the latter appearance, he observes that "a writer in the 'Times,' of about that date, describes an 'Astronomical Phenomenon,' which was 'a sudden lighting of the Pleiades of momentary duration,' and which took place twice on the same night. I observed the same effect produced by this meteor; and it is evidently owing to the proximity of the radiant R_3 to the Pleiades, causing the meteors to be seen foreshortened when they happen to present themselves in the position named."

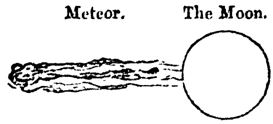
Large Meteors observed since the presentation of the last Report.

1871, August 13, $8^h\ 30^m$ P.M.—In a letter to Mr. Glaisher, Mr. W. J. Miller communicates the following observation of a fireball seen by him in August last at Glasgow:—" On the 13th inst., about $8^h\ 30^m$ P.M., I observed, about due north from the western part of this city, a meteor making a nearly vertical descent; it tended slightly westwards. The elevation might be about 25° or 30°; and the twilight was still strong. The effect on the eye was more of a flash of lightning, or the sudden appearance of the new moon, than any thing I can compare it to. The sky being clear, there could be no lightning of this description."

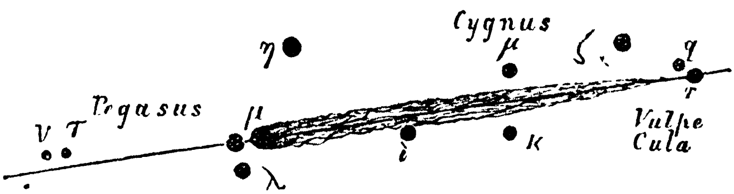
1871, August 21, about 9^h P.M.—The following description of a large meteor seen at Knocklong, Limerick, was communicated to the Committee by Mr. W. F. Denning in a letter from the observer, Mr. Jeremiah Henly, who writes:—" The meteor was visible a few minutes after 9 o'clock. It seemed to issue from about Polaris, and travelled across the heavens for a space of at least 7° or 8° [? 70° or 80°] in the direction of the constellation Hercules. As it passed through the atmosphere, it seemed to leave a brilliant track of fire across the heavens, which continued visible for about ten seconds."

1871, August 31, about $9^h\ 45^m$ P.M.—A meteor of very remarkable appearance was simultaneously observed at Hawkhurst (Kent) and at Ross (Herefordshire) under very favourable circumstances for determining its real height. The attention of a lady, Miss Strong, who observed the meteor near Ross, being directed, when it appeared, to the unclouded appearance of the full moon, which had then risen some 15° above the E.S.E. horizon; of a sudden the meteor came into view, with leisurely speed and with surprising lumi-

nosity, issuing, apparently, from close behind and from the centre of the moon's side. From this point of first appearance it glided slowly eastward, leaving on its track a train of gold-coloured sparks as broad and bright and compact, apparently, as the nucleus which it pursued. After advancing for a considerable space the nucleus disappeared instantaneously, as if it were suddenly extinguished; and the sweeping portion of the train nearest to the moon broke into separate sparks, while the train, along its whole length, lay scattered along the sky like sparkling dust, which quickly faded away. In the absence of any neighbouring stars, which were then only beginning to glimmer faintly in the evening light, no more exact description of its apparent course, after leaving the moon's side, could be successfully attempted.



A complete view of the meteor from its point of commencement, in a cloudless sky, was also obtained by Professor Herschel at Hawkhurst, in Kent, where it passed across the sky, at a considerable elevation, and with a long and brilliant course, at about $9^h\ 44^m$ P.M. In the first portion of its flight, which commenced close to the stars q, r Vulpeculæ, it increased from the brightness of a first-magnitude star to that of Sirius; and thence, while passing near the star ζ Cygni, it was accompanied on its course as far as the star μ Pegasi by a uniform and compact train of yellow sparks, of nearly the same brightness, and of twice the apparent diameter of the nucleus. The brightness of the meteor, in this part of its course, was but little less, and it at length exceeded that of the planet Venus at its greatest brilliancy, while its head was of the same yellow colour as the wide track of light which formed its train. At the latter point the bright nucleus disappeared, and



the luminous train of sparks ceased, while a small spark, about as bright as a fourth-magnitude star, with intermittent light, could be traced pursuing its course about 8° or 9° further, to a point about 2° below the star υ Pegasi, where it finally disappeared. The meteor moved over its whole apparent course of 40° in six seconds; and the bright belt of light, about 6′ in apparent width and 20° in length, which remained on its track, was visible for three or four seconds afterwards, resolving itself into small sparks, which appeared to move forwards along the streak in the direction in which the meteor had advanced. The perfect continuity of the long train of sparks, its little inferior brightness, similar golden-yellow colour, and general resemblance to the head, which it enclosed so completely on both sides as to exceed it considerably in width, and the steady forward motion of the meteor, caused it to strikingly resemble the sudden and horizontal discharge of a distant rocket. Such features of special interest in its appearance will, it may be hoped, from its brightness, and from the clearness of the sky on that evening, have attracted the attention of observers at other places, besides the two widely distant points of observation here recorded, at which its appearance

and the position of its apparent path in the heavens were noted under the most favourable conditions.

The point of commencement of the meteor's course is found with considerable certainty, from the two foregoing observations, to have been situated at a height of 44 miles above the sea, over a point in Pevensey Bay, about 6 miles from the Sussex coast. The real course of the meteor from this point was, nearly, from due west to due east, with a very slight inclination to the horizon; or that direction of its real flight is most nearly accordant with the observations. The point of disappearance of the small spark which advanced furthest along its flight was, hence, at a little lower elevation, of about 40 miles above the sea, close to the French coast, near Boulogne. Assuming that the moon's apparent place at Ross was exactly upon the apparent course of the meteor, which appears to be really signified by the remarkable observation that, as seen from that locality, the meteor appeared to issue from close behind the moon, the agreement of this point with that of the meteor's first appearance, as observed at Hawkhurst, in a graphical point of view, is so accurate and precise, that the real position of this point of the meteor's course, as above determined, may be satisfactorily assumed, without any material corrections, as being substantially correct. On the other hand, admitting that, for the purpose of calculation, the description of the remaining portion of the meteor's apparent course, as observed at Ross, is obviously incomplete, the narrow limits between which (conformably to the rough notes and sketches of its appearance there, and to the remaining portion of its apparent track as mapped at Hawkhurst) the meteor can be supposed to have moved, allows a very important conclusion to be drawn from a complete examination of the remaining materials which were recorded concerning its apparent course. If not exactly in the true west point of the horizon, the apparent radiant-point from which the meteor was directed can yet not have been far removed (not exceeding about 20°) southwards from this point, nor at any great elevation (not exceeding about 30°) above the western horizon, and it proceeded apparently from the radiant Q_3, near β Herculis, chiefly conspicuous in August; so that the direction of its real course relatively to the earth did not differ greatly (not more than 45) from that of the earth's real motion in its orbit at the time when the meteor appeared, which was nearly from the S.W. point of the horizon. The greatest length which can be assigned to the meteor's real path is rather less than 42 miles, derived from the supposition, as above assumed, that the meteor's real course was almost horizontal and almost exactly directed from the west. But if the meteor's real path was more inclined than this, it must also have been shorter (and with the above extreme inclination, which it might be possible to assign to it from the observations, its length would not exceed 33 miles*). As the whole duration of the meteor's flight, observed at Hawkhurst, was six seconds well counted while the meteor was in sight, the real velocity of its motion cannot have much exceeded seven miles per second; and under certain possible assumptions of its apparent course at Ross, it may even have been less than this, or the meteor may have travelled with a real speed of only 5½ miles per second. While the average real velocity of shooting-stars

* By supposing the meteor, as seen at Ross, after issuing from near the moon's place, to have descended obliquely at an angle of 45° with the horizon, towards the left. The drawings represent the meteor as slightly ascending, rather than descending; and it is described as advancing a considerable space, and producing a luminous train of some length, after leaving the moon's side. This representation of the meteor's apparent course at Ross, when compared with the Hawkhurst observation, agrees exactly with a perfectly horizontal real course, directed from about 4° south from west.

relatively to the earth is fully 30 miles per second, it follows that in this case, where the meteor was evidently overtaking the earth, moving nearly in the same direction with it, its real velocity in space must have exceeded that of the earth's motion in its orbit by not much more than 7 miles per second. The excess of the velocity of a meteor overtaking the earth directly in a parabolic orbit, above that of the earth's mean motion in its own nearly circular orbit, is found by Dr. Weiss to be about $9\frac{1}{2}$ miles per second*.

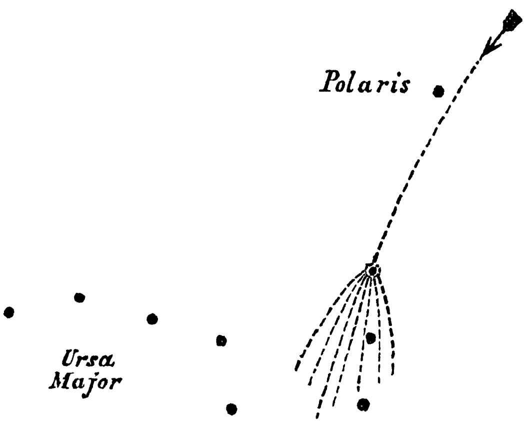
The following letter in 'Nature,' May 16, 1872, from Mr. G. C. Thomson, at Cardiff, affords another instance of bright meteors noted during the past year, the real course of which appears to have not differed greatly in their direction from that of the earth's motion in its orbit, at the time of their appearance:—"I observed a meteor at about half-past eleven on the night of the 8th inst., in the constellation Scorpio, which passed very close to the star Antares, travelling from right to left. It appears to me worth remarking, from the fact of its course lying very near and roughly parallel to that part of the ecliptic which corresponded to the earth's position in her orbit. It traversed some 8° or 10° of arc, and was visible for three or four seconds, gradually increasing in brightness until it was nearly on a par with Antares, which star it also resembled in colour. Its slow apparent motion immediately suggested the idea that it was moving in the same plane and direction as the earth, in fact that it was overtaking us in an orbit just outside our own. The course of another meteor seen about half an hour earlier from a westerly window, and described to me as not inferior to Jupiter in brightness, appears also to have lain in the direction of the ecliptic, but from left to right, in the neighbourhood of the constellations Gemini, Cancer, or Leo. It is rash to generalize from insufficient data; but I conceive these meteors may both have belonged to a system whose orbit lies nearly in the plane of the earth's orbit, the apparent retrograde motion of the last named being caused by the direction of its path crossing our orbit at a point behind the earth's then place, instead of in advance of it." The two meteors here noticed appear to have belonged to the meteor-system denoted by the radiant-point Y, presenting itself during the first half of May, near the centre of the constellation Leo, and scarcely more than 20° distant from the point in the ecliptic from which the earth's motion is directed during the early portion of that month. The apparent motion of the two meteors in opposite directions (in the former case moving eastwards towards Scorpius, and in the latter case westwards towards the constellations Gemini and Cancer) is most readily explained by the effect of perspective upon their, probably, not far from really parallel courses, joined with the circumstance that in their appearance above the observer's horizon, at Cardiff, the meteors successively presented themselves upon opposite sides of their common radiant-point. In relation to the probable positions of their apparent radiant-centres, both

* As a convenient means of exactly estimating the very short intervals of time occupied by meteors in their flight, it may be suggested to observers to repeat the English alphabet (or as many letters of it as are required, rapidly and distinctly) immediately after the meteor's appearance. With ordinary fluency of pronunciation one alphabet occupies about four seconds, and fifteen alphabets can usually be repeated in one minute, the time occupied by a single syllable, or by one letter of the alphabet, when thus repeated, being about one-sixth part of a second. By beginning the repetition during or immediately after the meteor's passage, and continuing it during an equal period of time to that in which it appeared to move, a pretty exact estimate of the interval may thus be obtained *from memory*. In ordinary cases (where the time of the meteor's passage does not allow more than five or six letters of the alphabet to be repeated) the observation may be repeated once or twice, and by counting the number of letters, in each case, a more exact average determination, amounting generally to a very close approximation, may be obtained.

the bright or reddish colour and the apparent speed of motion of meteors in their flight present a very important and interesting subject of study and of further observation.

1871, September 2, about 8^h 15^m P.M.—On this and the following dates some bright meteors, proceeding apparently from different radiant-points from that in Hercules of the meteor last described, were noticed, and the following was recorded by Mr. J. M. Wilson*, as it appeared to him on the above evening, in the fading twilight, and with a slightly clouded sky, and to other persons at Croakbourne, in the Isle of Man. The meteor appeared in the west, and presented a visible disk of about the apparent size of an eighth of the moon's surface. As it increased in size, the nucleus broke into three following and connected portions, the foremost and brightest of which was white; and a luminous streak remained for about one second upon the meteor's course. It moved for two or three seconds, with a slow and uniform motion, over a space of about 45°, descending nearly vertically in the west, from between the stars γ, π Herculis, crossing Corona to a little below ζ Bootis, where it finally disappeared, about 15° above the horizon.

1871, September 4, 9^h 30^m P.M.—At Brancepeth, near Durham, Mr. Joseph Lawson communicated the following description of a very brilliant meteor which he observed at the above hour; his shadow cast before him as strongly as during bright full moonlight, causing him to turn in time to see the meteor in its descent. It was first seen passing Polaris and descending towards Ursa Major (see the accompanying sketch); intensely white, like the



Meteor seen at Brancepeth, Durham, 9h 30m P.M., September 4, 1871.

magnesium light, and bursting into seven fragments as it approached that constellation. The two larger fragments appeared each to be not less than the head of the meteor before its disruption, and all were white, fringed with blue, and died out as sparks falling towards the earth, but apparently not reaching the horizon. The meteor burst with a momentary increase of light, and the fragments remained visible for about three seconds. No sound of an explosion was heard after the meteor's disappearance.

The following account of some bright meteors visible on the same evening

* 'Nature,' September 14, 1871.

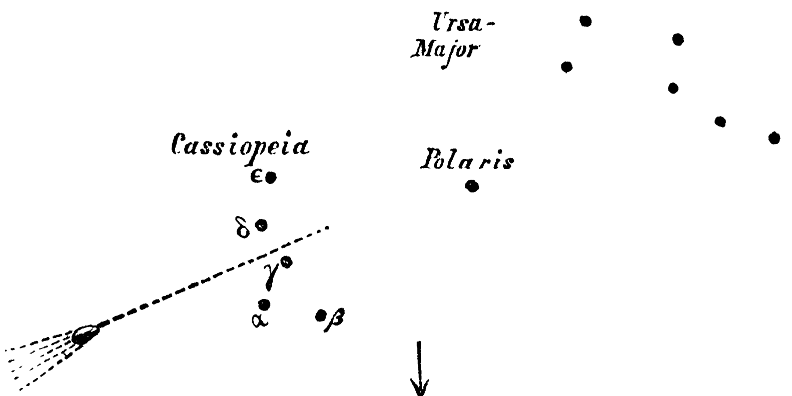
at Bristol was received from Mr. William F. Denning:—"On September 4 I noticed several shooting-stars that were quite conspicuous. At 9^h 40^m one passed slowly down from the N.E. to the north horizon. It was of globular form, and seemed to leave sparks in its flight. No train of light marked its path. This was the most brilliant one that I saw, and was equal, I imagine, to a star of the first magnitude." On the 10th of September, 1871, at 7^h 4^m P.M., a very brilliant meteor was also seen, while the daylight was yet too strong for any stars to be visible, by Mr. S. J. Johnson, at Upton Helions, near Crediton, in Devonshire, and by several other persons in that vicinity. It described, in about five seconds, a course of 15°, from an altitude of about 25° to an altitude of about 10° above the south horizon.

A large meteor is stated, in the 'Madras Times,' to have been observed at Trevandrum, in India, on the night of the 21st of October, 1871, which crossed the sky from the north, with rapid speed, in about four seconds, moving at an altitude of 35° or 40°*.

Some accounts of other bright meteors, noticed towards the end of last year, will be found described in the accompanying general list of such observations.

1872, Feb. 7, about 9^h 40^m P.M.—A second meteor of great brilliancy was seen by Mr. Joseph Lawson, near Brancepeth, Durham, on this evening, of which he communicated the following description:—

The meteor first appeared above and to the right of γ Cassiopeiæ, whence it described in about two seconds a downward course of about 30° towards the west, directed nearly from Polaris. It appeared small at first, but increased steadily until the apparent width of the head was about 30′ of arc, its uniform expansion strongly conveying the impression of a gradual approach



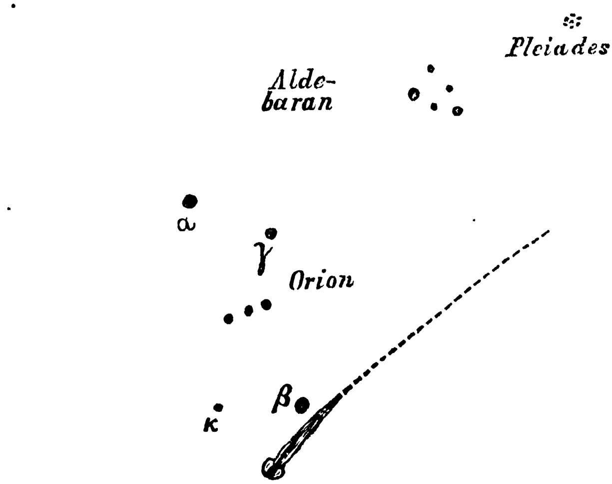
Position of a meteor's path among the stars, and its apparent perspective approach towards the observer, near Brancepeth, Durham.—Feb. 7th, 1872.

towards the observer's place. As it advanced the head became pear-shaped, intensely white, with a border of purple light, and it finally burst into several fragments, which appeared as very white sparks, advancing further upon the meteor's course, and speedily becoming red. The fragments disappeared from view behind the smoke of a neighbouring colliery, the noise of whose engines, close at hand, prevented the sound of a report, if any followed the meteor's explosion, from being heard.

1872, March 4, 7^h 45^m P.M.—A bright meteor seen at many places in

* 'Nature,' December 28, 1871.

England was thus described by Mr. T. Perkins, who observed it at Durham. The Durham Cathedral clock had just finished chiming the hour of a quarter to eight when the meteor appeared. The apparent size of the nucleus was much larger and its light was much brighter than that of the planet Venus, and it appeared of a brilliant greenish-blue colour. It described a course of



about 20°, with slow motion downwards, in about $2\frac{1}{2}$ seconds, and vanished suddenly (if it was not hidden by the branches of some neighbouring trees) at an apparent altitude of about 12° or 15° (as measured afterwards by the elevation of the trees) from the horizon. Its point of disappearance was about 8° or 10° below a point between the stars β and κ Orionis. Its path was slightly curved, as shown in the figure, and directed, in the latter portion of its flight, very nearly from the Pleiades.

Mr. S. H. Miller observed the appearance of the meteor near Wisbeach in Cambridgeshire, its light causing him to turn round and to note it in the last portion of its flight. In apparent size it appeared to be about one-third of the apparent diameter of the moon, perfectly white, like a drop of liquid silver, falling in the west, where it descended to the horizon.

At Northwich, in Cheshire, it appeared to cast as much light as the moon shining brightly in its first quarter. It shot from the direction of the Hyades, near Aldebaran, and disappeared close to Orion's belt ('Manchester 'Examiner and Times'). It also attracted attention at Bowdon near Manchester, where it was observed in the south-west, descending towards the S.S.E. horizon. It was at first accompanied by a reddish train, which changed to blue and left some sparks, when the meteor, with a dip southwards, suddenly disappeared. As seen at Bolton, near this point, by Mr. A. Greg, it appeared facing him (and to another observer, "low down in the sky" before him) as he looked towards the south; and it disappeared in a large and brilliant flash while passing over the belt of Orion.

1872, March 8, $9^h\ 5^m$.—The most brilliant meteor recorded during the year, and one of great interest from the southern character and much further westerly situation of its radiant-point than that of any meteor-system hitherto recognized during the period of that month, was observed by the assistant at Lord Rosse's Observatory at Birr Castle, in Ireland, and was thus described

in his note of its appearance communicated to 'Nature' of the 14th of March last by Lord Rosse:—

"Observed an intensely brilliant meteor. It was first seen in the region of Lepus, whence it moved with a slow and steady motion across the heavens to the S.E. horizon, where it gradually disappeared in a bank of cloud at about $9^h\ 5^m\ 19^s$ Greenwich mean time, having occupied 7 or 8 seconds in moving over 50° of a great circle. The time given may be a few seconds wrong, as it was noted by an ordinary watch. The head was intensely brilliant, of a bluish-white colour, and lighted up the whole sky.

"Its brightness was maintained during its entire visibility, and may have been as great as the moon at quadrature. Apparent diameter of the head 42′. It was followed by a very narrow tail about 3° in length, and of a reddish hue. It did not leave any phosphorescent train behind it; but at the latter part of its course it threw out some reddish luminous masses that gradually faded away. Its apparent course was in a great circle through β Canis Majoris to a point near the S.E. horizon in azimuth S. $28\frac{1}{2}$° E., and altitude $8\frac{1}{2}$°. For β Canis Majoris the azimuth was S. 20° 52′·4 W., and altitude 16° 43′·3. —Observatory, Birr Castle, March 8th, 1872."

It is to be regretted that a meteor of such unusual splendour and magnitude, which must (if clouds permitted) have been widely visible over the south of Ireland, and in the west and south-west parts of England, has not received any public or private notice which has hitherto come to the knowledge of the Committee, nor any apparent recognition from observers; while, if the important astronomical interest that attaches to its appearance is rightly understood, the great advantage of their investigation, if such have been preserved, it may yet be hoped, will prevail upon observers to communicate them to the Committee.

1872, April 12, $4^h\ 36^m$ P.M.—A fireball, not less brilliant, but, on account of its appearing in the daytime, probably less conspicuous than the preceding meteor, was seen on the afternoon of the above day by Mr. Whipple, at the Kew Observatory, by whom the following observations of its appearance were recorded*:—

"Yesterday afternoon, whilst standing on the lawn of the observatory, with my back to the sun, which was brightly shining, I saw a splendid meteor fall in the south-east. The sky at the time was of an intense blue, and cloudless, with the exception of a few cirri in the north and north-west, and the meteor, as seen against it, presented the appearance of polished silver. The flight of the meteor was almost vertical, at an altitude of about 30°; its extent was about 10°, and the tail, which seemed to hang in the air and fade away like the tail of a rocket, was, at the instant of explosion, probably 3° in length. There was no report accompanying its disruption, or it would certainly have been heard, the neighbourhood being very still at the time. Immediately on its disappearance I looked at my watch; it was $4^h\ 36^m$ P.M., Greenwich mean time. Had the fall occurred after dark, I have no doubt but that the meteor would have exhibited a magnificent spectacle; for its brilliancy far exceeded that of the moon as seen by daylight."

1871, December 6th, $8^h\ 14^m$ P.M., or $8^h\ 15^m$ P.M.—A meteor of great brilliancy was recorded at the former hour at Birmingham by Mr. Wood, and at the latter hour at Beeston Observatory, near Nottingham, by Mr. Lowe. The descriptions of these meteors, which are included in the following general list, differ in some important physical respects, which might almost lead to an independent conclusion that two different meteors were observed. The meteor

* 'Nature,' April 18, 1872.

seen by Mr. Wood at Birmingham was deep blue; its nucleus disappeared without apparent expansion or explosion, and left a very slight, evanescent streak upon its course. The meteor observed by Mr. Lowe at Beeston was distinctly red; it burst with a flash, and left a very enduring streak of red points upon its course. With these essential differences of character (and even with the short interval of only one minute between the times of their observations), the identity of the meteor seen at Beeston with that observed by himself is regarded by Mr. Wood as not sufficiently established, or as being at least open to question, in the absence of further observation. The recorded positions of the meteors' paths are, moreover, so close to each other, that although they present a small displacement in the right direction to be produced by the great distance (about 45 miles) between the observers' places at Beeston and Birmingham, yet the unusual height of 360 miles above the earth at first appearance, and of 240 miles at disappearance, which their comparison together would suppose, must be regarded as requiring a proof from further observations, of which none have hitherto been received by the Committee.

III. Aërolites.

The following accounts of two aërolites which fell last year are extracted from the scientific journals in which their descriptions have recently appeared.

1. Searsmont, Maine, U.S., 1871, May 21, 8^h A.M. (local time).—Professor Shephard, of Amherst College, Massachusetts, has published some particulars respecting the meteoric stone which fell at Searsmont, Maine, U.S., on May 21st. About 8 A.M. there was heard an explosion, like the report of a heavy gun, followed by a rushing sound resembling the escape of steam from a boiler. The stone fell in a field, and a lady who was in a house close by saw the earth scattered in all directions as it entered the ground. The hole which it made was soon found, and on digging down the fragments were found still quite hot, the outside surfaces showing plainly the effects of melting heat. The largest piece weighed two pounds, and the fragments altogether twelve pounds. They emitted an odour like that of flints when rubbed violently together. The hole made by the falling body was two feet in depth, the soil being a hard coarse gravel; but the fracture of the stone was obviously occasioned by its striking against three large pebbles, each about four pounds in weight. Professor Shephard obtained and examined the largest fragment of the aërolite. Fully one half of its surface was coated with the original crust, and the shape would seem to denote that the perfect mass had been of an oval, subconical figure with a flattish base, so as on the whole to have approached the shape of the famous Duralla stone now in the British Museum. Among the constituent elements were found meteoric iron, peroxide of iron, chladnite, troilite, together with a single blackish mass which Professor Shephard considered was in all probability a plumbaginous aggregate. The following notice of its composition has also recently appeared:—

"This meteoric stone has been examined by Dr. Lawrence Smith (Silliman's 'American Journal of Science,' September 1871, p. 200). He finds it resemble very closely the Mauerkirchen stone that fell in 1768, the crusts corresponding quite closely both in thickness and appearance; the Mauerkirchen stone, however, has not well-marked globules like that of Searsmont, and in this respect it corresponds more nearly to the Aussun aërolite. Its specific gravity was 3·701, and its composition is—

Nickeliferous iron	14·63
Magnetic pyrites	3·06
Olivine	43·04
Bronzite, a hornblende with a little albite or orthoclase, and chrome iron	39·27
	100·00

With the bronzite there may also be some enstatite, which would be confounded with the former if existing in the stone."

2. Montereau (Seine et Marne), France, November 1871.—"It is stated that an aërolite weighing 127 lbs. fell lately near Montereau (Seine et Marne), in France. It appears to have come from the east, and burst with a loud explosion, giving a bright blue light. It is of an irregular spheroid shape, and black, and is to be sent to the Academy of Sciences."—'Nature,' November 30th, 1871.

IV. Meteoric Showers.

In the prosecution of a system of observations on the annual meteor-showers of the past year, proposed to engage the constant attention of the Committee since their last Report, a more than usually abundant series of successful observations were made, exhibiting with greater completeness than in previous years the general character of the displays, which have presented themselves with more than ordinary prominency on each of the annual shower-meteor dates.

A first description of the observations collected at the several British Association Stations on the nights of the 9th to the 12th of August last is contained in the Quarterly Journal of the Meteorological Society for the 15th of November, 1871, where the numbers of meteors mapped at the different stations, and their rate of frequency at certain places where their numbers were counted in successive hours and half-hours, were for the most part fully stated. The following are some additional observations relating especially to this latter point, and to the general characters of the August shower in 1871, as they were recorded by the different observers.

The numbers seen per hour by Mr. Wood at Birmingham were, on the night of the 9th twelve, on the 10th twenty-four, and on the 11th sixteen. The meteors came in groups, with lulls; they were mostly small, and with a much larger proportion than usual of orange-coloured and train-bearing meteors.

In the watch kept by Captain Maclear at the Royal Naval College at Portsmouth on the night of the 10th, the sky was throughout clear or overspread with such a slight haze as only occasionally to dim the faintest stars; and all the brightest meteors visible were noted between 11 o'clock P.M. and 2 o'clock A.M. from a favourable point of view upon the College roof, where a number of the brightest meteors visible between $11^h\ 45^m$ and $12^h\ 45^m$ was also added to the list by Lieutenant Mathias, whose attention was directed towards a different quarter of the sky; and the number of meteors visible in a somewhat less favourable position between 10^h and 11^h P.M. was also counted alone by Captain Maclear. Deducting one quarter of the meteors seen between $11^h\ 45^m$ and $12^h\ 45^m$ as having been observed by Lieut. Mathias, the remaining numbers of bright meteors seen by Captain Maclear alone in the successive half-hours ending, during the night of

Aug. 10th, at	$10^h\ 30^m$,	11^h,	$11^h\ 30^m$,	12^h,	$12^h\ 30^m$,	13^h,	$13^h\ 30^m$,	14^h,	Total
were	5	10	10	12	21	22	14	23	117,

showing an increase in the rate of frequency until the end of the watch.

Besides those noted, many smaller meteors passed unrecorded, about two thirds of the meteors counted being as bright as first, and some of the rest as bright as second-magnitude stars. But few meteors were visible on the night of the 9th; and twelve were seen between 9^h and 10^h P.M. on the 11th. Between 10^h and 11^h P.M. on the 11th no shooting-star was visible, although the sky was then as clear as it had been during the previous hour, or on the night of the 10th. A bright meteor shot downwards through Corona soon after 10^h 30^m, and a remarkably large one close to Saturn soon after 10^h 45^m P.M. on the 10th. The latter meteor was pear-shaped; it lighted up the objects round the observer, and burst at the end of its course like a shell.

This meteor was also seen at Cardiff, and was described, in a communication to Mr. Glaisher on the meteors of that evening by Mr. G. C. Thompson, as follows:—"Aug. 10th, 10^h 51^m P.M. Meteor equal to or larger than Venus; from direction of α_1, α_2 Capricorni, downwards towards the west (right hand), inclined about 60° to the horizon. Beautiful light-green hue. Near the end of its course it seemed to divide into several fragments, or a small cloud of sparks." It was also visible at Greenwich, where the following notes of its appearance were recorded by Mr. Glaisher's staff of observers at the Royal Observatory:—"Aug. 10th, 10^h 51^m 15^s P.M. Brighter than Jupiter; pale green; duration of flight 0·7 second; length of course 5°: left a fine train. Meteor pear-shaped; from 12° below, and to right of Antares, fell perpendicularly." At Hawkhurst a broad red flash, like that of lightning, was visible in the sky at 10^h 50^m P.M.; but the meteor itself was not seen. It was, however, well seen in the neighbourhood of Hawkhurst, and a pretty accurate measurement of its apparent path by objects near which it appeared to pass was there obtained. It fell nearly vertically from about 20° to about 3° or 4° above the horizon, 60° W. from magnetic south, with no great speed; and it appeared to burst, with sparks, when at its brightest. At 11^h 2^m, Paris time, corresponding within a few minutes with the time of this observation, a meteor of twice the brilliancy of Venus, of strong whitish light, like an electric spark, was also seen in the south by the observers of M. Le Verrier's staff at St. Lo, on the French coast of the English Channel, and at Angers on the Loire.

Of the other bright meteors seen at Portsmouth on the night of the 10th, one descended towards the east, and burst at disappearance, at about 12^h 45^m; and one passed across Polaris at 12^h 55^m. At about 1^h 30^m a bright green meteor appeared in the S.S.E., at an altitude of about 10°, moving towards the S.S.W. Shortly afterwards a very bright one passed across Pegasus towards the S.W., with an explosion at disappearance. One of the last two meteors may not impossibly be identical with a fireball observed by the observers of M. Le Verrier's staff at Trémont at 1^h 32^m 49^s (Paris time) on the same night, which passed from R.A. 235°, N.P.D. 29°, to R.A. 233°, N.P.D. 39°, and burst at disappearance with a strong red light, leaving a luminous streak upon its course that was visible for 33 seconds.

On each evening of the shower the numbers of the meteors were also noted, under favourable conditions of the sky, by Mr. W. F. Denning, at Bristol, with the following results:—

		Meteors.			Meteors.
Aug. 9..	11^h 30^m to 12^h	7	Aug. 11..	10^h 35^m to 10^h 50^m	18
„ 9..	12^h to 13^h	27	„ 11..	11^h to 12^h	29
„ 9..	13^h to 14^h	8	„ 11..	12^h to 12^h 15^m	16
„ 9..	14^h to 15^h	21	„ 11..	12^h 15^m to 12^h 30^m	15
„ 10..	10^h to 11^h	17	„ 11..	12^h 30^m to 13^h	23
„ 10..	11^h to 12^h	27	„ 11..	13^h to 13^h 15^m	11
„ 10..	12^h to 12^h 30^m	27	„ 11..	13^h 15^m to 13^h 30^m	14

Attention was principally directed to the northern sky, and many meteors doubtless escaped observation. Most of those observed were especially small ones; those seen on the 9th were nearly all minute and scarcely discernible. Several brilliant ones were seen, however. At $12^h\ 23^m$ on August 10, a meteor of great lustre, and star-like in appearance, diverged from Perseus towards the horizon. It was of a blue colour, and left a luminous streak which was visible for about four seconds.

At $10^h\ 44^m$ on August 11, another brilliant one, about as bright as Venus, was visible in Ursa Minor, and the train of light which it left was visible for a few seconds. It was, however, at $12^h\ 50^m$ on the latter date that the most brilliant meteor was seen. It passed between the fourth-magnitude stars ϵ and ζ Cygni, and soon afterwards disappeared, leaving a train of light which endured for about seven seconds. This one, like the great majority of those observed, radiated from or nearly from the small star B Camelopardi.

The first of these bright meteors corresponds with an observation at Cardiff, contained in the description of the star-shower on the 10th of August communicated to Mr. Glaisher by Mr. G. C. Thompson :—"August 11, $12^h\ 22^m$ A.M.—A meteor, as bright as Venus, passing downwards between α and β Aurigæ, from the direction of the sword-handle in Perseus. Fine purple colour; leaving a portion of phosphorescent train visible for about half a minute, which had, I think, a lateral drifting motion in the direction of β Aurigæ."

No sound followed the explosion of any of these meteors. Mr. Denning adds the following list of observations of the same shower by Mr. Edmund Neison in London, who was assisted in his watch for the meteors by two friends, and who recorded the numbers visible on successive nights.

Meteors observed in August 1871.

Date.	Time.	Bright meteors.	Total number.	No. per hour.	Remarks.
	h m h m				
August 6.....	9 58 to 10 47 (49^m)	6	15	18	Two extremely brilliant.
„ 7.....	8 58 to 10 35 ($1^h\ 37^m$)	17	43	27	Four extremely brilliant.
„ 8.....	9 45 to 10 18 (33^m)	11	29	53	Two extremely brilliant.
„ 9.....	9 5 to 10 31 ($1^h\ 26^m$)	21	62	43	Five very brilliant.
„ 10.....	10 7 to 10 58 (51^m)	31	90	106	Four very brilliant.
„ 11.....	Cloudy; clear but for 5^m	1	2	...	One very bright.
„ 12.....	9 55 to 10 26 (31^m)	10	20	39	Three very bright.
„ 13.....	9 0 to 9 56 (56^m)	10	25	27	Two very brilliant.
Totals	$6^h\ 48^m$	107	286		

The total number of meteors observable was, without doubt, over 500, as only about one half of the sky was kept under view. The following particulars were recorded of some of the most brilliant meteors which came under observation.

Date.		Time.			Remarks.
		h	m	s	
August	6	9	58	0	From α Cassiopeiæ to α Andromedæ. Very brilliant blue meteor, leaving a long streak.
„	6	10	40	0	A very bright meteor traversed the centre of Ursa Major.
„	7	10	15	0	From near α Herculis to Libra. Left a bright yellow train.
„	7	10	27	0	From β Ophiuchi to Saturn.
„	7	10	35	30	From β Pegasi to α Aquarii.
„	8	9	45	0	From Cassiopeia to Cygnus. Left a bright streak.
„	8	10	7	0	From α Lyræ (Vega) to Sagittarius. Left a long train
„	9	9	50	0	From Cassiopeia to α Lyræ.
„	9	9	52	0	From Cassiopeia to Cygnus.
„	9	10	12	0	From Lyra to Pegasus.
„	9	10	17	0	From Cassiopeia to Delphinus, leaving a long train.
„	9	10	30	0	From Cassiopeia to γ Pegasi. Left a long train.
„	10	10	5	0	From β Cygni to α Aquilæ. Yellow.
„	10	10	40	0	From Draco to Serpens. Left a long train.
„	10	10	45	0	From Lyra to Ophiuchus. Left a long yellow train.
„	10	10	50	0	From Cassiopeia to Lyra. Left a long, pale-blue train.
„	10	10	55	0	From Cassiopeia to Cepheus. Left a long train.
„	11	10	10	0	From Aquila to Sagittarius.
„	12	10	3	0	Along the Milky Way to Saturn.
„	12	10	7	0	Towards the south, near Saturn.
„	12	10	16	0	From η Pegasi to Andromeda. Left a streak.
„	13	9	33	0	From Cepheus to Perseus. Left a brilliant train.
„	13	9	56	0	From Capricornus to Sagittarius. Fast and brilliant.

At Hawkhurst the appearance of the last meteor but one of this list, on the 13th, was recorded at $9^h\ 32^m$, slowly and steadily increasing to a bolide of about the brightness of Venus, of nearly white or pale yellow colour, tapering behind to a narrow train, which marked its track for a few seconds. It first appeared close to h Ursæ Majoris, and fell perpendicularly, about 12° along a line drawn from φ Draconis, or from between the stars ϵ and ζ Ursæ Minoris, towards the horizon. The meteor appeared in full view, and the point of first appearance and the length and direction of its flight (apparently from Draco) were very exactly noted.

A detailed description of the various meteors of the shower recorded at the Radcliffe Observatory, at Oxford, was also obligingly communicated to the Committee by Mr. Main. The meteors were chiefly observed by Mr. Lucas, who was occasionally assisted by Mr. Keating; and the following Table shows the number of the meteors which were noted on the successive nights.

Date.	Time.	No. of meteors.	No. recorded per hour.	Remarks.
	h m h m			
Aug. 7...	9 40 to 13 0 ($3^h\ 20^m$)	10	3	Watch kept until $13^h\ 30^m$; no meteors as bright as 1st-mag. stars observed.
„ 8...	9 30 to 14 49 ($5^h\ 19^m$)	47	9	Watch until 15^h. Motion of the meteors mostly very rapid. Eleven meteors = 1st-mag. stars.
„ 9..	9 11 to 14 57 ($5^h\ 46^m$)	57	10	Watched from 8^h to $15^h\ 30^m$. Seven meteors = 1st-mag. stars.
„ 10...	9 8 to 14 44 ($5^h\ 36^m$)	100	18	Watched from $8^h\ 30^m$ to 15^h. Four meteors brighter than the fixed stars. Seventeen meteors = 1st-mag. stars.
„ 11..	9 1 to 15 9 ($6^h\ 8^m$)	102	17	Watched from $8^h\ 30^m$ to $15^h\ 10^m$. Three meteors brighter than the fixed stars. Nineteen meteors = 1st-mag. stars.
Totals ...	$26^h\ 9^m$	316		

The following particulars of some of the most remarkable meteors are contained in the list of observations, of which a full description will be included in the forthcoming printed volume of the Radcliffe Observations.

Date.	Time. h m	Remarks.
August 8...	12 30	Meteor=1st-mag. *; white; duration one second. Shot from χ Draconis to α Coronæ. Curved path and long train.
„ 8...	13 40	Meteor=1st-mag. *; white; duration two or three seconds. Shot past α Lyræ *northwards*, leaving a streak.
„ 9...	9 14	Mr. Keating saw a meteor pass through the field of the Transit-circle while looking for a star near the south horizon.
„ 9...	10 55	Meteor=2nd-mag. *; duration one and a half second. From θ Cassiopeiæ to δ Cygni. Meteor with a long course and streak.
„ 9...	12 18	Meteor=1st-mag. *; duration one and a half second. Shot from α Delphini past β Aquilæ, leaving a streak.
„ 9...	13 26	Two meteors=2nd-mag. *s appeared in quick succession, with an interval of about one second between them, passing on nearly the same course from a point near α Piscium towards η Ceti.
„ 9...	14 45	Meteor=2nd-mag. *; white; duration two seconds Passed from χ Draconis, just under Polaris, ⟶. This meteor had the slowest motion of any observed in this night's watch.
„ 10...	10 22	Brighter than a 1st-mag. *; red. Shot from β Pegasi to a point near β Aquarii. This meteor rapidly followed two other meteors equal to 2nd and 1st-mag. *s in Bootes, and directed from β Andromedæ to γ Pegasi.
„ 10...	10 51	A flash of red light from the south was visible in the sky, resembling lightning. [Meteoric. See above.]
„ 10...	11 17	As bright as Jupiter; duration two seconds. From a point under γ Ursæ Majoris to the north horizon.
„ 10..	12 30	Brighter than a 1st-mag. *; yellow. Passed from γ Camelopardi† to α Ursæ Majoris, leaving a brilliant train, about 15′ in width, visible for about fifteen seconds, just under Polaris, after the meteor had disappeared. Certainly the most brilliant train I have ever seen. A streamer-looking appearance was visible in the place for half an hour, and was recognized by Mr. Keating at 13^h 0^m. [The meteor was also seen at Leamington, and, as will shortly be described, by Mr. Greg, at Manchester.]
„ 10..	14 10	Meteor=1st-mag. *, white; duration one second. Passed from a point near γ Cygni to η Pegasi. [From radiant in Cygnus.] At 14^h 13^m two meteors=4th-mag. *s, appeared at the same instant moving in parallel paths between β and η, and between α and γ, across the constellation Pegasus.
„ 11...	10 14	Brighter than a 1st-mag. *; duration one and a half second. Shot from η Persei, increasing in brightness, and changing from red to blue, and leaving a streak, until it burst over γ Andromedæ.
„ 11....	10 55	Meteor=1st-mag. *; duration one second. Passed from α Cygni to a point south of α Lyræ, leaving a bright train. This train was in two parallel lines, which slowly joined together sideways, and then disappeared (Mr. Keating).
„ 11..	12 6	Two fourth-magnitude meteors, with an interval of two seconds between them, shot from ζ Aquarii to δ Capricorni, and from α Aquarii to β Aquarii.
„ 11...	12 36	As bright as Jupiter. From a point between β and ζ Draconis to halfway between α Coronæ and α Ophiuchi. Left a train visible for five or six seconds. (The beginning of the meteor's course not well seen.)
„ 11..	12 54	As bright as Jupiter; yellow. From ι Tauri to a little below Aldebaran. Left a streak.
„ 11...	14 4	Two second and fourth-magnitude meteors appeared immediately following each other from γ Ursæ Minoris to between η and θ Draconis, and from a point just over *h* Ursæ Majoris, descending vertically.

† Known in maps of Bode's Constellations as the star *m* Custodis.

The following observations of the shower by Mr. R. P. Greg, at Manchester, on the night of the 10th, and at Bolton on the nights of the 11th and 12th, describe the unusual appearance of one of the most remarkable meteors recorded in the above list:—"The number of the meteors was larger than usual, though not remarkably so. On the 10th and 11th, between 10^h 30^m and 12^h, I did not perceive much difference in the horary numbers: perhaps four or five in a minute for two observers; coming sometimes four or five nearly together, and then several minutes passing without any being visible. On the evening of the 12th there was a great falling off, not only in the numbers, but also in the size and flashing train peculiar to the Perseïds. At about 9^h 30^m P.M. on the 10th, before I looked out, I heard that a splendid meteor was seen here.

"At 12^h 31^m, on the night of the 10-11th of August, a very remarkable meteor appeared in the S.E., which I hope may have been doubly observed, although it was visible after the time appointed for the simultaneous watch. It commenced close to β Andromedæ, moving nearly on a line from η Persei to a point a little beyond the star γ Pegasi, which it almost crossed, describing a course of 10° or 12° in about two seconds. The nucleus had a sensible disk of about 2′ in diameter, and, together with the train, showed prismatic colours. The train lasted twenty or thirty seconds, and soon assumed a serpentine appearance. It was one of the most beautiful meteors I have seen. About four or five seconds after it had disappeared, it broke out again five or six degrees further on, near λ Piscium, moving exactly in the same direction, apparently the same meteor over again, about half its former size, but with the same colours, and leaving a bright streak on this part of its course for about three seconds. What appears most unaccountable was that it broke out again three or four seconds, at least, after it should have done, had it been the same meteor continuing onwards at the same velocity. It seemed, instead, to be another meteor, although it must have been the same; but how its speed could be so checked after it first ceased to be visible, and it could then go on at the same speed as before, I do not know."

The results of the regular observations made at the Royal Observatory at Greenwich, by Mr. Glaisher's staff of observers, are, in point of numbers and of the brightness of the meteors seen, very similar to those obtained at Oxford, the watch on the nights of the 10th and 11th being kept for about six hours and four and a half hours, and during from two to three hours on each of the remaining nights. The total number of meteors mapped, by the parties of from one to four observers who watched during a space of about 25^h 50^m on the different nights was 470; and the average number per hour, with that of the meteors equal to or brighter than first-magnitude stars alone, recorded on each night is shown in the following Table:—

Date, 1871, August		6	7	8	9	10	11	12	13
Average hourly numbers of	Bright meteors	4	5	5	9	14	9	4	3
	Total mapped	8	10	14	20	28	$20\frac{1}{2}$	14	9
No. of observers		1	2	2	3	4	2	2	2

The first meteor, equal to or exceeding the brightness of Jupiter, seen during the display was that already noticed, which was recorded at 10^h 51^m P.M. on the night of the 10th. At 9^h 30^m P.M. on the 11th a bluish-white meteor, brighter than Venus, appeared low down near the eastern horizon, immediately below γ Andromedæ. At 10^h 15^m P.M. on the same evening a similar meteor, brighter than Jupiter, appeared near *b* Lyncis, and moved about 15° in $1\frac{1}{3}$ second in a direction from *c* Camelopardi, leaving a bright streak for three seconds. A meteor of the same magnitude, which appeared

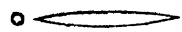
at 10^h 23^m 30^s P.M. on the evening of the 12th, and which left a fine streak, moved from a different radiant-point, for about $1\frac{1}{4}$ second, in a course of 10° between β and η Pegasi, from the direction of θ Piscium. At 10^h 46^m and 11^h 7^m P.M., on the same evening, meteors of greenish colour were seen, leaving long and bright streaks; that of the first was visible for fourteen seconds; and the meteor (as will shortly be described) was also seen at Hawkhurst. The last brilliant meteor of the shower was visible at 10^h 35^m P.M. on the 13th, of greenish colour, like the last two, and leaving an exceedingly bright streak, which was visible for six seconds after the meteor had disappeared. It passed from the direction of η Persei, about 1° below Polaris and β Ursæ Minoris. At about the same time, or shortly before 11 o'clock on the evening of the 13th, a brilliant meteor appears to have been seen at Regent's Park, London, among other meteors of the shower which there still continued to be plentiful. A notable example of the meteors occasionally appearing in groups occurred at 10^h 49^m P.M. on the 10th, when three meteors, about as bright as second-magnitude stars, appeared within an interval of about ten seconds, and all passed in a nearly identical path in continuation of a line joining γ Andromedæ and α Trianguli. Two meteors, brighter than first-magnitude stars, also appeared within four seconds of each other, moving in parallel and closely neighbouring courses, inclined about 45° towards the horizon, in the constellation Capricornus, at 11^h 4^m 20^s P.M. on the 10th. This brilliant pair was simultaneously observed at Hawkhurst, each meteor about the brightness of Sirius, leaving a long, bright, and slender streak. The first commencing about 2° above β Aquarii, moved on a course exactly parallel to that of the second, which passed, with the same steady speed as the first, from half a degree below ζ Aquarii to half a degree below δ Capricorni. Mr. Wood, at Birmingham, also noted the appearance, at the same minute, and within about two seconds of each other, of this perfectly matched and closely adjacent pair. Each meteor was about as bright as Sirius, of orange colour, lasted one second, and left a reddish streak upon its course. The path of the first, as seen at Birmingham, was from θ Aquarii to δ Capricorni; and that of the second was parallel and closely adjoining to it from a point in R. A. 325°, S. Decl. 22°, to R. A. 321°, S. Decl. 26°. Closely as all these descriptions of them correspond together, the unfavourable position of their apparent paths near the horizon prevents the real heights and the distances of the component meteors of the pair from each other and from the observers from being calculated with the accuracy and certainty that would otherwise have been attainable from such excellent observations.

Almost all the meteors observed at Greenwich during the display left more or less brilliant and enduring streaks. With the exception of one reddish, four white, eight pale green or greenish, and twenty-six yellowish meteors (in all about 8 per cent.), all the meteors mapped at Greenwich were uniformly of a bluish or bluish-white colour.

As seen on the nights of the 10th and 11th in London, the following is Mr. Crumplen's description of the August meteors:—"The sky was quite clear, but there was an auroral glare in the north, and a white streamer flickering for a few minutes on the evening of the 10th*. Eighty-two

* The auroral streamer was also seen by Mr. W. H. Jackson at Tooting near London, who writes:—"On the 10th there was a tolerably distinct aurora borealis, one streamer of which extended from the north to a spot apparently a considerable distance beyond Arcturus." At York a distinct auroral arch was seen by Mr. J. E. Clark on the 6th, lasting from after twilight, when it first appeared, until 11^h 30^m, when it was obscured by the rising moon. A similar faint appearance was observed by Professor Herschel, at Glasgow, on the evening of the 7th.

meteors were counted between 9^h 30^m and midnight, of which forty-six fell during the last hour. The courses of fifty-six bright meteors were mapped during a watch of about eight hours on the nights of the 9th, 10th, and 11th, with an average hourly rate of appearance, for one observer, of three bright meteors on the 9th, nine on the 10th, and ten on the 11th, all of them directed from Perseus. The Perseïds were of all magnitudes, but the greater number of bright ones (in proportion to the number visible) made their appearance on the 11th. They presented the appearances common to the meteors of this radiant; and some of them left brilliant streaks of blue light, which expanded after the disappearance of the nucleus, fading gradually from the ends towards the centre. In several instances I noticed that the nucleus was apparently separate from the train, the brighter ones reminding me very much of the corresponding shower of 1863."



On the nights of the 10th and 11th the sky was overcast at Edinburgh and Glasgow; but several bright meteors were seen at Glasgow on the nights of the 7th, 8th, and 9th by Professor Herschel, one of which shot with a flash overhead at about 12^h 48^m A.M. on the 9th, resembling faint lightning. At Edinburgh on the 9th, and at Sunderland on the 11th and 12th, the paths of fifteen Perseïds were also mapped by Mr. T. W. Backhouse, although the sky was obscured at Sunderland by thick fog and haze. At Knocklong in Ireland a good view of the shower was obtained by Mr. Jeremiah Henly, whose description of its appearance was communicated to the Committee by Mr. W. F. Denning:—"Although I did not reckon the actual number visible, I considered that more meteors appeared on the 11th than on the 10th. On the 11th, in about three hours, I witnessed thirty-three of remarkable brilliancy, while on the 10th, in the same space of time, only twenty-seven of a similar character were visible; but the smaller meteors I did not reckon on either night." Mr. Denning also regarded the shower at Bristol as at least as intense on the second as on the first night of its appearance, and thus describes the principal characters of the meteors seen:—"The majority of the meteors were accompanied with trains, which, however, disappeared immediately on the extinction of the head. Most of those seen were white, but several appeared blue, and some of a yellow colour. No sound was heard after the explosion of any of them. The meteors were most numerous on the night of the 11th–12th; and the same was the case in the year 1869, according to my own observations."

At Hawkhurst the paths of 107 bright meteors were recorded with more or less detail by one observer, during a watch of about ten hours, on the nights of the 9th–13th of August, lasting about three hours (until shortly after midnight) on each of the first three nights, and for a shorter time on the other two. The average hourly numbers noted on the former nights were six bright meteors on the 9th, sixteen on the 10th, and eleven of similar character on the 11th. Three brilliant meteors appeared on the night of the 12th, and one on the night of the 13th, among ten bright ones recorded in an hour on the former, and seven in the same time on the latter night. Of these, the first (already stated to have been seen at the Royal Observatory, Greenwich) appeared at 10^h 46^m 30^s P.M., with a sensible disk and apparently fully as bright as Venus, of dazzling bluish-white light, crossing β Ursæ Minoris from a point about half a degree below Polaris, beginning at R. A. 40°, N. Decl. $89\frac{1}{2}°$, and ending at R. A. 225°, N. Decl. 75°. It left a bright streak which remained visible, on its whole course for about

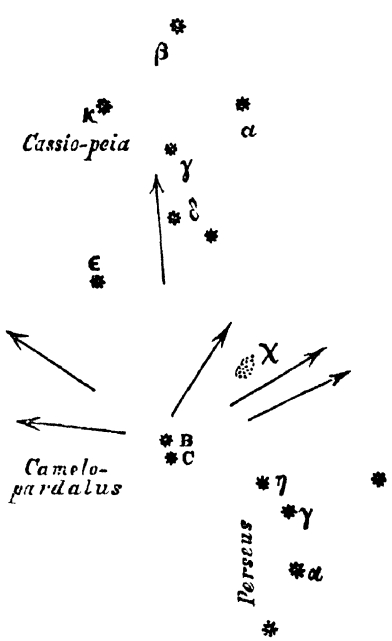
three seconds. At the Royal Observatory, Greenwich, the meteor, of pale-green colour, leaving a bright streak visible for fourteen seconds, moved in about two seconds from ι Cassiopeiæ across β Cephei, almost to α Lyræ. The other two bright meteors seen at Hawkhurst on the 12th were scarcely inferior in brightness to this one. That which appeared at $11^h\ 16^m$ passed from τ Pegasi to a point midway between γ Piscium and ζ Aquarii, changing from blue to yellow colour as it increased, and leaving a bright streak for a few seconds on its course. The second was observed at $11^h\ 34^m$, passing in fully one and a half second over 30° or 40° of arc from the star β Andromedæ, along a line directed from δ Cassiopeiæ and inclined about 50° to the horizon. It left a bright streak for some seconds on its course, which was broken into two, or had two maxima of brightness at two different points of its length. The apparent paths of these two meteors were:—

			R. A. N. Decl.		R. A. N. Decl.
August 12. .	$11^h\ 16^m > ♀$.	Began at	$348° + 22°$.	Ended at	$343° + 6°$
,,	$11^h\ 34^m = ♀$.	,,	$15 + 35$	,,	$13 + 16\frac{1}{2}$

The trains of most of the meteors seen at Hawkhurst were bluish and rather faint, except when seen foreshortened. They sometimes distinctly spread out after the star had disappeared, and grew gauze-like. They rarely resembled the golden-yellow dotted lines which have sometimes been seen to mark the track of bright meteors in former August showers.

Position of the Radiant-point.

At Bristol, on the evening of the 10th, Mr. W. F. Denning "saw several small meteors which, from their various paths, must have been in close proximity to a radiant-point which is undoubtedly situated at R. A. $2^h\ 30^m$ ($37\frac{1}{2}°$), N. Decl. 58° 30′. This is about $3\frac{1}{2}°$ S.W. of the sword-handle of Perseus, and between χ Persei and B Camelopardi. I saw several small meteors whose paths were extremely short, that came exactly from the place I have indicated. The annexed is a rough delineation of a few of the meteors' paths that were observed in the neighbourhood of this radiant-point in Camelopardalus. There were many other meteors whose paths were conformable to B Camelopardi; and there appears no doubt as to this being the radiant-point, or rather the principal one."



London, August 10th.—On this evening the radiant-point appeared to Mr. Crumplen to be for most of the meteors near χ Persei; but another radiant-point higher up in the sky was quite apparent for some of them. "In the case of every meteor, whether mapped or counted, I ran my eye back along the track to determine, if possible, the true radiant-point. It

appeared clear enough to me that there was more than one radiant, or that a somewhat extensive space of the sky would be required if the tracks of all the meteors were to be included in it. I believe, however, that the great majority of the meteors will be found to have diverged from a spot rather higher than the famous cluster in Perseus (33 Ḩ vi), say about ·1° above. Meteors from this point have been plentiful each evening, and three quarters of those observed between 11^h and 12^h on the 10th came from there. I noticed that these followed each other rapidly, and that after a lull for a few minutes, a radiant still higher would manifest itself, as will be indicated by the map. The radiants in Ursa Major, Cygnus, and Pegasus were also active, especially the latter; but with one or two exceptions these meteors were not particularly noted."

From a very full projection of more than 300 meteors seen at York between the 5th and the 12th of August, Mr. J. E. Clark obtained the proportions of the meteors directed from each of the principal radiant-points of the shower in 1871. "The proportion of the Perseïds observed was about 85 per cent., from Cygnus 7 per cent., from the radiant below ϵ Pegasi about $4\frac{1}{2}$ per cent., from Polaris about 2 per cent., and from an apparent radiant-point in Aquarius about 1 per cent. One meteor was observed in Auriga, apparently from a radiant-point near β Aurigæ.

"The main radiant on the 10th, as shown by the mapped courses, lay close to η Persei; but very many were directed from α Persei, or even lower still, whilst a large number extended the radiant to χ. Besides the central radiant, there seemed to be one or two outlying points from which the tracks appear to diverge. One of these seems to be between β and γ Andromedæ, and another by c Camelopardi.

"Of meteors almost stationary, the best was one seen by Mr. Waller and Mr. Brown just by η Persei on the 8th. I observed some nearly so, near γ Persei on the 8th, below η on the 10th, and at χ on the 11th, also by ν Draconis on the 10th; and Mr. Brown saw one by ρ Cephei on the 8th."

In a letter in 'Nature' of August 17, 1871, Mr. Clark communicates the numbers of the meteors seen on each night, together with some further particulars regarding the above radiant-points, which are here appended.

"Having been engaged during the past week in observations on the August meteors, I thought a few of the results might be interesting to some of your numerous subscribers. My regular observations extended from Sunday night to Friday night; and, as the following Table will show, the weather was, with the exception of one night, as favourable as could reasonably be desired. From over 120 meteors mapped down (out of about 330 seen) it is evident that the principal radiant-point, or rather line, is a line drawn from α Persei to γ Persei, and onwards towards η. One bright meteor was seen on the 8th, just below η Persei, which did not move more than $\frac{1}{6}°$ in a second of time, and left a *cloud* behind it lasting about two seconds. A remarkable feature was the *outlying* radiants, as they appeared to be, one of which was situated at or near θ Cassiopeiæ, another near the star c of Camelopardalus. The radiant situated between δ Cygni and γ Draconis is very well marked; also a radiant near γ Cephei (where another almost stationary meteor was observed), and one just below ϵ Pegasi, towards α Aquarii; associated apparently with the last is a radiant near the small lozenge in Delphinus, above α Aquilæ.

"In the following list of 312 meteors observed here, 242, or about 77 per cent., were from the Perseus radiant or radiants:—

"*Meteors seen August* 1871, *at York.*

Date.	Hours.	State of sky.	Number observed.	Number observed from Perseus.	Proportion.
	h m h m				
August 5...	10 0–10 10	Fine	6	5	·83
„ 6...	10 20–12 0	Fine	34	28	·82
„ 7...	10 0–12 0	Fine	49	30	·61
„ 8...	10 0–12 0	Fine, till 11·45, then cloudy ...	50	31	·62
„ 9...	10 30–11 30	Cloudy and hazy .	6	4	·6
„ 10...	9 55–12 5	Few clouds at times, and very slight haze	120	106	·88
„ 11...	9 55–12 5	Ditto	47	38	·80

"Generally two watching, sometimes three, and once or twice but one. For the 10th I had a list of twenty-six others handed me, observed by a friend close at hand, of which nineteen were from Perseus.

"J. Edmund Clark."

"20 Bootham, York, August 14."

At Birmingham the position of the radiant-point appeared to Mr. Wood to have undergone no change from its apparent place as described in former years.

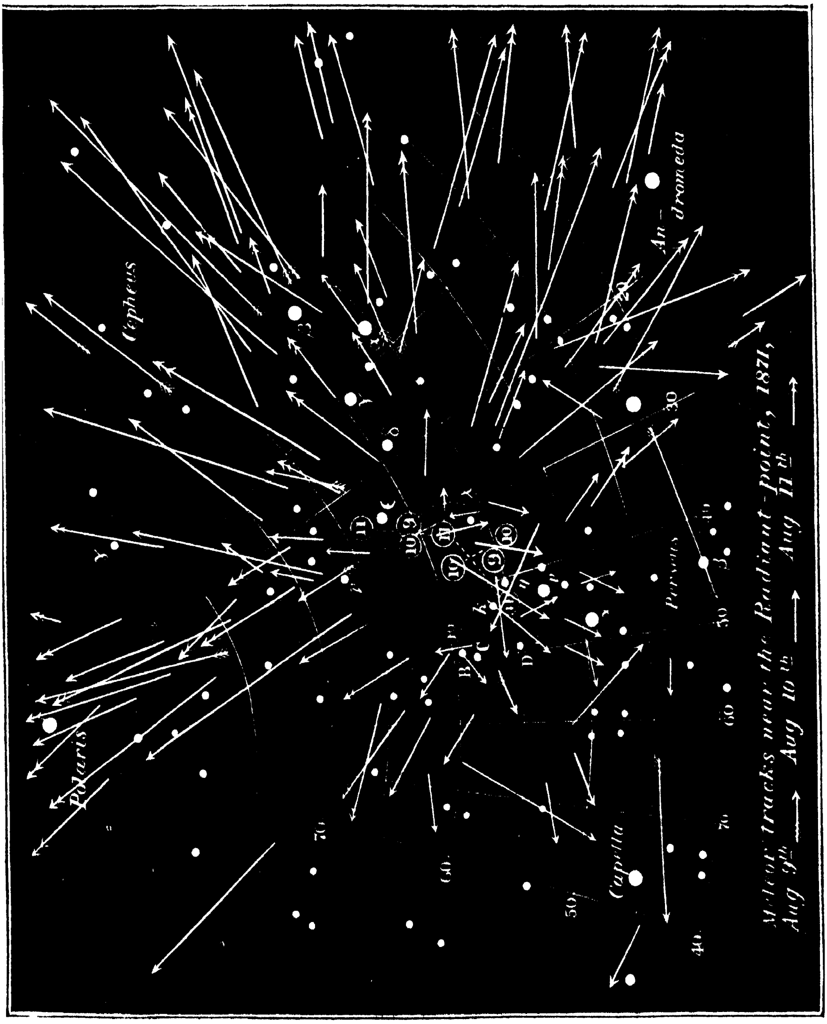
At Manchester on the 10th, and at Bolton on the 11th and 12th, Mr. Greg noted especially the short meteors near the radiant-point in order to determine, if possible, its real place. On the night of the 10th it appeared to be situated about halfway between η and χ Persei, on the 11th exactly at η, and on the 12th about halfway between η and γ Persei. In relation to these results Mr. Greg observes:—"There can, I think, be little doubt, judging from my own observations, that this year the radiant-point was lengthened out on a line between χ and γ Persei, with the centre precisely at η (or k), that there was a tendency to move with the time from χ towards γ, and that on the night of the 11th the tendency to accurate radiation was unusually precise. Probably accuracy of radiation is a symptom of a particular shower being at its maximum intensity, with the individual meteors less scattered than at periods of its minimum display. I saw so very few meteors move near the radiant, either up or down, that I cannot so precisely state the position of the radiant-point in right ascension as in declination."

Among the list of meteors received by the Committee from the observers of the August shower in 1871, the paths of 316 meteors noted on the nights of the 9th, 10th, and 11th of August were sufficiently well indicated to be correctly delineated on suitable star-maps. Of the whole number nine were directed from a radiant-point near the north pole of the heavens, at about R. A. 10°, N. Decl. 82°; fourteen proceeded from a radiant-point in Cygnus, apparently close to δ Cygni, at about R. A. 293°, N. Decl. 42°; and thirty-three meteors diverged from radiant-points in or near the constellations Pegasus and Aquarius. Of the remaining number a few meteors appeared to be very erratic or sporadic, and about 250 were distinctly members of the shower diverging from the radiant-point in Perseus. The long duration of the shower appearing to offer a favourable opportunity for ascertaining if the position of the radiant-point underwent a sensible change during the time of its continuance, the recorded apparent paths of all the Perseïds noted during successive intervals of ten minutes on each of the nights of observation were

projected upon separate maps. A similar projection of the paths of the meteors recorded at the Royal Observatory at Greenwich on the night of the 10th of August was also made upon a separate map for each interval of ten minutes during the hours of observation. With the exception of the period between 9^h and 10^h P.M. on the 10th among the Greenwich observations, and between $9^h 45^m$ and $10^h 45^m$ P.M. on the same evening among those of the British-Association observers, when 40 per cent. of all the meteors mapped diverged very accurately from a centre of radiation at about R. A. 34°, N. Decl. 61° nearly midway between χ Persei and ι Cassiopeiæ, and a very marked activity of this radiant-point during the following hours of both those series of observations until midnight on the 10th, no tendency to accurate divergence from a single radiant-point during any sustained period was observable during the continuance of the shower. A radiant-point near η Persei, which was also discernible among the British-Association observations on each evening of the shower, presented itself most conspicuously in those made at Greenwich on the evening of the 10th, towards midnight, and by the intersection of its meteor-tracks with others from the more northern radiant, appeared to give rise to a prominent centre of divergence after midnight between γ and ϵ Cassiopeiæ, which may have owed its apparent activity to the simultaneous existence of the former pair. The general radiant-point of the meteoric shower at Greenwich on the night of the 10th was very nearly the principal one already indicated, with a tendency, especially after midnight, of some meteors to come from directions nearer to η and to γ Persei. All the meteor-tracks noted by the British-Association observers between $9^h 36^m$ and $12^h 44^m$ on the 10th having been projected upon a single map with the radiant-point in Perseus near the centre of the projection, a densely crowded region of intersection of the tracks prolonged backwards was found to occupy a roughly triangular space of about 10° in length along each side, having its centre very nearly at the above indicated spot in R. A. 36°, N. Decl. 58°, and its angles in nearly symmetrical positions at points in R. A. 31°, N. Decl. 61°, R. A. 36°, N. Decl. 53°, and R. A. 45°, N. Decl. 59°, as shown by the small circles marked (10) in the accompanying figure. The first of these points corresponds very closely with the definite radiant-point, which was most conspicuous during the early portion of the shower.

On the night of the 11th the principal intersection of meteor-tracks recorded at the Royal Observatory, Greenwich, was still close to the latter point, at R. A. 31°, N. Decl. 62°, during the hours of observation from 9^h until $13^h 30^m$, with subordinate points of intersection at B and D Camelopardi, and between η and P Persei. A projection of all the tracks recorded by the British-Association observers between $9^h 45^m$ and 13^h on this night having been made on a similar map to that prepared for the observations of the 10th, the principal centre of divergence was found to be placed not far from its position on the previous night, a few degrees northward from χ Persei, at R. A. 31°, N. Decl. 58°. A meteor with very short course appearing close to this point marked its position very nearly. The tracks of the remaining meteors were almost evenly distributed round it, within distances which included nearly all the courses of 12° or 15° from its centre. But other apparent centres of radiation also presented themselves somewhat definitely near the north and south borders of the radiant-region, in the neighbourhood of ϵ Cassiopeiæ and η Persei, at points in R. A. 25°, N. Decl. 63°, and R. A. 42°, N. Decl. 55°, as shown in the figure by the small circles marked (11), forming apparent outliers of the central point.

On the night of the 9th of August the apparent paths of 38 Perseïds recorded by the British-Association observers between 9^h and $12^h\ 50^m$ appear to have diverged from two definite radiant-points of nearly equal intensity at the extremities of an oval space, extending from η Persei to near ϵ Cassiopeiæ, through which nearly all the recorded paths prolonged backwards passed. These points were situated in R. A. 29°, N. Decl. 60°, and R. A. 39°, +55°.



The general centre of divergence of the Perseïds during the whole period of greatest intensity of the shower on the nights of the 9th-12th of August, 1871, was shown by the combined results of these observations to be a few degrees northwards from the star χ Persei, and not far from a point in R. A. 35°, N. Decl. 59°, which is the average place obtained by giving equal weight to all the separate radiant-centres shown in the figure, of which the positions

were determined from the observations of the shower communicated to the Committee by the observers for the British Association. The figure represents in plane perspective the apparent paths of all the Perseïds noted on the nights of the 9th, 10th, and 11th of August, 1871, whose visible tracks were in the immediate vicinity of the general radian-tregion of the shower.

Meteor-showers in October, 1871.—On the night of October 14th, between 11^h and 12^h P.M., six meteors, as bright or brighter than 1st-magnitude stars, were observed at Hawkhurst in one hour, radiating with considerable accuracy from a point near the head of Aries, and close to the point of first appearance on this date of the radiant R_3 in Musca, which appears to contribute bright meteors from the direction of this constellation during the principal meteor-showers of October, November, and December, but from which so many bright meteors in one hour as those seen at Hawkhurst on the above date form an exceptional display. Another meteor, like one noted on this date, as bright as Sirius, proceeded from the same radiant-point, passing overhead at Hawkhurst, and leaving a faint streak, at 11^h 45^m P.M. on the 19th; and two scarcely less brilliant members of the same meteor-shower appeared, with short courses and slow motion, near the radiant-point on the 21st of October. Three or four bright meteors with swift motion and leaving bright streaks on their tracks, proceeding apparently from circumpolar radiants near $A_{14,15}$ and $F_{1,2}$ in Cassiopeia and Auriga, were noted during the same short watch at Hawkhurst which was kept on each of those dates. The sky was overcast with rain and wind on the nights of the 18th and 19th at Hawkhurst, and at all the other places from which communications were received; and although occasional openings of the clouds allowed a few stars to be seen at Hawkhurst, where the single bright meteor last noticed was observed, and at Tooting, where Mr. H. W. Jackson kept a watch for them whenever the state of the sky permitted, no other shooting-stars were recorded. But in a moderately clear sky, from 7^h 45^m until 11^h P.M. on the 18th, six meteors of some brightness were mapped at the Royal Observatory, Greenwich, two of which were directed from R_3, one from the north pole, and the rest from a radiant-point near $A_{14,15}$ in Cassiopeia, or $F_{1,2}$ in Auriga.

On the night of the 20th the sky remained overcast at the southern stations; but at Birmingham, Sunderland, and Glasgow a few meteors were visible through fog and haze, which generally obscured all stars less bright than the third magnitude, until nearly midnight, when the sky gradually became more clear. Three small shooting-stars were observed at Glasgow by Mr. R. M'Clure between 11^h and 12^h P.M., and two by Mr. Wood at Birmingham, as described in his observations on the shower.

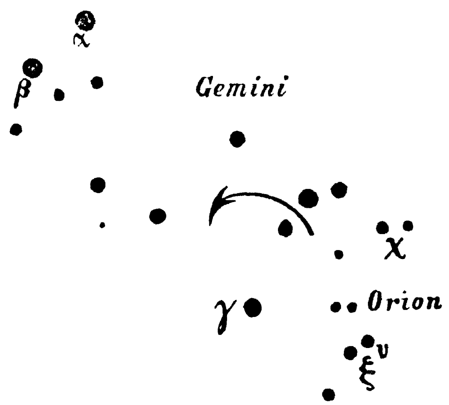
Between 9 o'clock and midnight on the same evening, four meteors, three of which were directed nearly from R_3, and one apparently from the north pole, were observed by Mr. T. W. Backhouse at Sunderland; they were unconformable to the radiant O (Schiaparelli, No. 36, B. A. Report for 1870, p. 98), or to any of the other radiant-points noted by Mr. Backhouse in the morning hours of this and the two following nights. Another bright and unconformable meteor, seen on the same night, was also directed from the north pole; while the twenty-one remaining meteors, seen in the course of about two hours of observation on the mornings of the 21st, 22nd, and 23rd (and all but three on the earlier dates), indicated the return of the October meteors, and presented some contemporaneous radiant-points, of which Mr. Backhouse gives the following description in his remarks on these results of his observations:—

"The meteors marked A [twelve meteors noted in about an hour and a

half on the mornings of the 21st and 22nd, and another on the morning of the 23rd] in the list belong to Schiaparelli's Radiant No. 36 *, and those marked C [two meteors noted on the last morning of the watch] to his No. 37 †. Those marked B [five meteors seen on the mornings of the first two nights] have a radiant-point in R. A. 113°, N. Decl. 58° ‡; but, owing to the remarkable swiftness of these meteors, this point can be only approximate. I make the radiant-point of A at R. A. 97°, N. Decl. 15°, taking the observations of all three nights. The meteors marked U were unconformable to all these showers. It will be seen that only *one* of these appeared in any of the mornings, and *no* unconformable ones in the evenings.

"The hourly rate of frequency of meteors of all kinds, at that time of morning at which they were most numerous, was on the 20th [morning of the 21st] 19, on the 21st 12, on the 22nd 8."

None of the shooting-stars observed at Hawkhurst, or at the Royal Observatory, Greenwich, on the evenings of the 14th and 18th of October were directed from the radiant-point in Orion; but on the night of the 21st the tracks of eleven meteors from this radiant-point were mapped at Hawkhurst between the hours of $11^h\ 30^m$ and $13^h\ 30^m$, and an approximate position of the radiant-point was obtained. This appeared to be between the stars γ, ν Geminorum and ν Orionis. A small meteor, almost instantaneous, near this point described a short path, which appeared curved towards Castor and Pollux, and which lay in the sky like a bent whip (see the sketch) between γ Geminorum and ζ Tauri, at about R. A. 90°, N. Decl. 20°. The last meteor of the shower seen at Hawkhurst on this night was directed from the point C, between Castor and Pollux, regarded by Mr. Backhouse as having furnished a few meteors on the morning of the 23rd of October, at Sunderland, during his observations of this shower.



With regard to the appearance of the October meteors at Birmingham, Mr. Wood communicated to the Committee the following results of his observations of the shower in the past and in previous years:—

Luminous Meteors.

Birmingham. Epoch 19th October. W. H. Wood.

The meteoric shower of the above epoch has not been visible from this station since 1868; and the following are the unpublished results of those

* Brit. Assoc. Report for 1870, p. 98.—Oct. 21. Near γ Geminorum, at R. A. 96°, N. Decl. 13°. Apparently identical with the radiant O, near ν Orionis, described in previous Reports, of the meteor-shower on October 18–21.

† Ibid. Between Castor and Pollux, on October 21–25. About 17° or 18° from Schiaparelli's position of the former radiant-point.

‡ Connected, apparently, with the radiants $F_{1,2}$ [Report for 1868, p. 403], from the middle of September to the latter end of November, at R. A. 83°, N. Decl. 50°, near α, β, and δ Aurigæ.

observations, together with those of the succeeding years, to the present date (1871):—

Meteoric Shower, October 19, 1868.

Centres of radiation and the number per cent. from each.

Radiant.	per cent.
O	= 57
$A_{14,15}$	= 7
A_{16}	= 10
F_2................	= 10
$R_{1,2}+R_3$	= 10
$U+G+T_{2,3,4}$	= 6

Probable time of maximum, 18th–19th.

Percentage of colours.

Orange or yellow........	= 40
Blue	= 40
White	= 20

Percentage of magnitudes.

Equal to Sirius	= 13
,, 1st mag.	= 20
,, 2nd mag.	= 23
,, 3rd mag. and under	= 44

43 per cent. left reddish trains.

Rate of Apparition.

Date.	Hour (G. M. T.).	Number of meteors registered.	Hourly average.	State of the sky.
18.	12.0 to 12.30 A.M.	6	12	Clear.
18.	9.45 P.M. to 10 P.M.	1	4	Hazy; overcast at 10.45.
19.	10.30 P.M. to 11.30 P.M.	4	4	Foggy; stars dim.
19.	11.30 P.M. to 12.30 A.M.	10	10	Clear.
20.	P.M.	..	..	Overcast.
21.	10.45 P.M. to 11.45 P.M.	6	6	Clear.

As far as the weather permitted observations, it would seem probable that this shower was above the average of its kind in hourly numbers seen, and presented its distinctive features of ruddy meteors leaving trains, of which 57 per cent. emanated from the radiant O in Orion; the remainder issued from seven other radiants. Few meteors were seen before 11.30.

1869, October 19, P.M.—The brightness of the full moon obscured the meteors (if any).

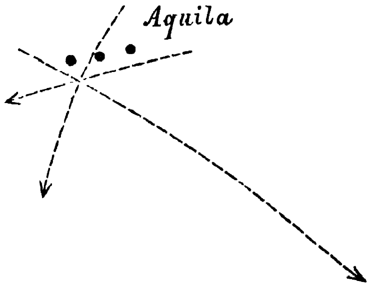
October 19, 1870.—From the 18th to the 20th stormy weather (P.M.).

October 19, 1871.—18th, overcast. 19th, overcast; heavy rains (P.M.). 20th, foggy; from 10.20 to 11.20 P.M. 2 meteors: 11.10 P.M., 2nd mag., blue, 0·5 sec.; from 86,+53, to 74,+50; radiant F_1; left a streak (the other meteor was not observed accurately enough for mapping: 10.35 P.M., ruddy, 2nd mag., in head of Cetus, rad. O ?).

Meteor-showers of November 1871.—At Brancepeth, Durham, Mr. Joseph Lawson noticed some conspicuous shooting-stars on the evening of the 8th of November, of which he gives the following description:—"On Wednesday, the 8th, at about 6 P.M., I saw four meteors in five minutes; the brightest about the 2nd magnitude. One passed through Corona, the other three were all through Aquila; but their directions were such that I could see no radiant-point. One described a course of fully 60° (see the accompanying sketch, p. 95)."

From a report of observations at Sunderland received from Mr. Backhouse, it appears that one or two meteors from Leo were visible on the

evening of the 8th of November, between half-past 10 and half-past 11 o'clock, one of which, at $10^h 37^m$, was perfectly similar to the Leonids in all respects, and was as bright as Sirius. A 2nd-magnitude meteor, leaving a long streak, also shot between Aries and Cetus from the direction of the Pleiades and of the head of Leo as late as the evening of the 18th of November, quite resembling in its appearance, and being perfectly conformable to the radiant-point of that well-known group. The following notice of a contemporaneous radiant-point accompanies Mr. Backhouse's description of his observations of the shower :—



"I enclose a Table of the most important meteors that I saw last month. Those marked L are Leonids, and those marked R_4 are conformable to Heis's radiant-point R_4*. I was surprised to see two Leonids so early as November 8; although the path of that at $10^h 37^m$ was not quite in the right direction for the great shower of the 13th, I have not the least doubt that it was one of them, for it was exactly like them. I watched for the Leonids for 25 minutes on the 12th [morning of the 13th], between $16^h 17^m$ and $17^h 25^m$, and saw two. The next night was throughout cloudy, whenever I looked out, with very small gaps in the clouds, so I saw no meteors." Besides the Leonids here noticed five meteors directed from the radiant-point R_4 were seen on the nights of the 8th and 9th of November.

At the Royal Observatory, Greenwich, the sky was overcast on the nights of the 11th and 13th, and only clear at intervals on that of the 12th. A watch was, however, kept on the last two of these nights until after 3 o'clock on the morning of the 13th, and until daybreak on the morning of the 14th of November, and the apparent courses of about thirty shooting-stars were mapped. Of these, four on each night proceeded, roughly, from the direction of Leo, the remaining meteor-courses being chiefly directed from Taurus and from other contemporaneous radiant-points in other parts of the sky. On the night of the 14-15th the sky was again quite overcast; and as far as could be gathered from the observations under such unfavourable conditions, the number of the Leonids observed was two or three times less than that of the meteors visible from other radiant-points, or of the sporadic meteors visible on an ordinary November night; and no distinct return of the November meteor-shower at the Royal Observatory, Greenwich, could be recorded as having been visible on the annual dates in the year 1871.

Although cloudy on the previous and the following nights, the sky was remarkably clear at Hawkhurst on the night of the 13th-14th of November; and a watch for the November meteors was kept from half-past eleven until half-past one, and again for about half an hour soon after two o'clock. The first Leonid was visible at $11^h 33^m$, as bright as Jupiter, passing in a long course and leaving a long streak from under Ursa Minor to the N.W. horizon. In the following two hours twelve Leonids and twenty-six other meteors, none of very great brilliancy, were noted, and their courses were mapped by one observer. The unconformable shooting-stars all proceeded from a radiant-region in or near the space contained between the heads of Taurus and Orion

* Also noticed by Mr. Backhouse on the 4th and 6th of November, 1869; see these Reports for 1870, p. 97.

and the feet of Gemini and Auriga, while the Leonids were directed from a better-defined radiant-region in the head of Leo. Two more Leonids, and two other meteors belonging to the group from Taurus, were recorded during the short watch between 2^h and $2^h\ 30^m$ A.M. on the 14th. One accordant observation of a meteor from Taurus, simultaneously observed at the Royal Observatory, Greenwich, at $12^h\ 3^m\ 12^s$, was obtained; and the comparative rate of frequency of the Leonids and of the unconformable or sporadic meteors visible during the same watch nearly confirmed the results of the watch kept by Mr. Glaisher's staff of observers at the latter place.

At the observatory of Stonyhurst College the Rev. S. J. Perry obtained an uninterrupted view of the November meteors during several hours of their appearance on the morning of the 13th of November; and the following results are obtained from the list of meteors which he observed. The sky was overcast until $10^h\ 15^m$ P.M. on the 12th (when a regular watch was commenced), and was clear, with the exception of a few stratus clouds, until $3^h\ 15^m$, when it became quite clear, and remained so until the end of the watch at $6^h\ 30^m$ A.M. on the morning of the 13th. The times and other particulars of the appearance of fifty-five meteors were recorded, with the positions of their apparent paths among the stars. Of these about twenty were Leonids, and fifteen, seven of which were Leonids, were as bright as first-magnitude stars. The following numbers of shooting-stars, and of the meteors which appeared to radiate from Leo, were observed in the successive hours ending at—

1871, Nov. 13th, A.M...	12^h	13^h	14^h	3^h	4^h	5^h	6^h	$6^h\ 30^m$	Totals
Nos. of meteors seen ..	4	9	6	12	3	7	10	4	55
Nos. of Leonids	2	1	0	7	1	1	6	2	20

The majority of the unconformable meteors noted during the watch proceeded from the directions of those parts of Gemini, Orion, Taurus, and Auriga near the head stars of Orion, or between the Hyades, the Pleiades, and the Twins.

"In the watch for meteors kept under the direction of M. Le Verrier in France, on the nights of the 12th, 13th, and 14th of November, those observed on the 12th and 13th issued from a point in the neighbourhood of the constellation Auriga; the 'Leonides,' or meteors issuing from Leo, were most numerous on the night of the 14th" (Notes from the 'Comptes Rendus' of Nov. 20, 1871, in 'Nature' of Nov. 30, 1871).

The following description of the November meteors, as they appeared at Newcastle-on-Tyne on the morning of the 15th of November, 1871, was communicated in a letter from Professor Herschel, in 'Nature' of the 30th of November:—

"Shortly before four o'clock on the morning of the 15th the clouds cleared off, and the appearance of several meteors, one of which was as bright as Jupiter, gave evident signs of the progress of the November star-shower. The perfect clearness and darkness of the sky, in the absence of the moon, at the same time gave especial brightness to the meteors and to their phosphorescent streaks. Between four o'clock and the first approach of daylight, at six o'clock, thirty-two meteors were counted, or at the rate of sixteen per hour, of which three were as bright, or brighter, than first-magnitude stars, nine as bright as second, six as bright as third, and eight no brighter than stars of the fourth or lesser magnitudes. Twenty-six of these meteors were directed from the usual radiant-point in Leo, which on this occasion, although not very well defined, appeared to be approximately close to the star Zeta, in

Leo's sickle. About one half of their number left persistent streaks, which sometimes appeared to grow brighter after the meteors had disappeared; and I vainly endeavoured to bring them into the field of view of the direct-vision prisms of a small spectroscope, the duration of the brightest streaks noted scarcely ever exceeding one or two seconds. A very brilliant meteor, casting around a flash like that of lightning, was seen here shortly after nine o'clock on the evening of the 13th (and its appearance was also noted at Woodburn), traversing the north-west sky. These particulars, imperfect as they were, unfortunately, rendered by the cloudy weather, are the only descriptions of the November star-shower which its appearance here has hitherto enabled me to supply.

"A. S. Herschel."

"Newcastle-on-Tyne, Nov. 17."

Meteor-shower of December 12th, 1871.—Arrangements similar to those made for observing the other meteor-showers of the past year were prepared by the Committee in expectation of the return of the December meteors in 1871. On the evenings of the 5th and 9th, and on the night of the 12th and 13th, Mr. T. W. Backhouse recorded eighteen shooting-stars seen at Ilkley in Yorkshire and at Sunderland, one of which on the 1st, and most of those seen on the latter dates, were directed very nearly from the usual radiant-point in Gemini. Three of those noted on the 5th proceeded from the Radiants $A_{14, 15, 16}$ near Cassiopeia, the appearance of which in November and December has been supposed to be connected, not improbably, with the periodical returns of Biela's comet. Although the clouded state of the sky prevented any meteors from being seen at Sunderland during the hours appointed for observations on the evenings of the 11th, 12th, and 13th, three meteors from Gemini were seen on the evening of the 11th, and two others during a short watch on the morning of the 13th, when the sky was clear; while only three meteors unconformable to the same radiant-point were recorded by Mr. Backhouse during the time in which these five meteors of the December star-shower were observed. On the nights following the periodic dates, it will be seen from his report that very few meteors directed from the well-known radiant-point of this annual star-shower were observed. "On the 13th [morning of the 14th] I watched for 25 minutes, about 16^h and 17^h (it was equal to about 9 minutes' watch in a cloudless sky), and I only saw one meteor; it was not a 'Geminid.' On the 14th [morning of the 15th] I watched for 45 minutes in a cloudless sky between $17^h\ 15^m$ and $18^h\ 21^m$, and saw nine meteors, all in the first 26 minutes. No radiant-point was, however, discernible; one was a 'Geminid,' appearing at $17^h\ 36^m$. It was of the fifth magnitude, and disappeared at $\frac{1}{2}$ (π Leonis, 15 Sextantis)." A bright meteor, described in the foregoing accounts of large meteors, directed apparently from the radiant-point A_{16}, was seen by Mr. Backhouse on the evening of the last-named date.

At the Royal Observatory, Greenwich, the sky was generally overcast on the periodic nights, and only one small meteor, on the evening of the 12th, unconformable to Gemini, was observed.

At Hawkhurst the sky was occasionally cloudy on the evening of the 12th until 11^h, when it became quite clear, and a constant watch for shooting-stars was kept between $10^h\ 15^m$ P.M. and midnight. Thirty shooting-stars were observed, of which fourteen were visible before 11 o'clock. The apparent courses of twenty-six of these meteors projected upon a map showed that eight were unconformable to, and of the remaining number four appeared to

be very erratic members of, the group directed from the radiant-point in Gemini. The tracks of fourteen (or 54 per cent. of those mapped) prolonged backwards passed through a small circle about 12° in diameter, having its centre about 3° from Castor, towards θ Geminorum, at R. A. 108°, N. Decl. 33°, which was the apparent centre of divergence of the shower. About one-half of the "Geminids" were brighter than second-magnitude stars, and two of the brightest left a persistent streak of light on their course. They appeared white, and their apparent motion was, in general, not swift. On the evening of the 13th the sky at Hawkhurst was completely overcast.

At Tooting, near London, a watch for their appearance was kept for $1^h\ 20^m$, between $9^h\ 40^m$ and $11^h\ 20^m$, by Mr. H. W. Jackson; the sky was quite clear, and the apparent paths of seven meteors directed from Gemini were recorded on a map. Prolonged backwards the tracks of these "Geminids" all crossed a small circle not more than 8° or 10° in diameter, whose centre was nearly midway between Castor and Pollux (slightly towards the neighbouring star ι Geminorum), at R. A. 112°, N. Decl. 30°. In his remarks on this night's observations Mr. Jackson observes that his attention was wholly given to recording the apparent courses of the meteors with exactness, so that their apparent places of appearance and disappearance, as drawn upon the map, were probably not more than half a degree in error either way; and all the meteors whose apparent paths were drawn upon the map were satisfactorily well observed. No particular attention was accordingly given to the appearances of meteors from other radiant-points, nor to the various characters of brightness, duration, and of leaving persistent streaks which were presented by the Geminids that were observed. On the evening of the 13th the sky at Tooting was completely overcast.

A definite radiant-point of the shower very near to the latter position appears also to be indicated by the appearance of one of the meteors of the December group, with a very short course, on the same evening, as observed by Mr. W. F. Denning at Bristol. The sky was generally unfavourable for observations on both evenings of the 12th and 13th of December; but the descent of a large meteor (as described in the foregoing list) was noted near the western horizon at $9^h\ 42^m$, and three other meteors were seen during a short interval of a quarter of an hour on the night of the 12th, when the sky was clear, and a watch was kept by Mr. Denning for the return of the December meteors. "At $10^h\ 3^m$ P.M. a small meteor was seen. It was evidently in close proximity to the radiant-point, its path being very short, and not extending over more than one or two degrees. It diverged from ι Geminorum (about 4° S. of Castor), and was of momentary duration. The direction of its extremely short path seemed to be towards the zenith.

"At $10^h\ 18^m$ I saw a much brighter meteor. It emanated from Gemini, and passed to the horizon in the south. One part of the path occupied a place about 8° south of Rigel in Orion; there was no train. Other meteors were seen, but the exceedingly clouded state of the sky rendered it impossible to note their paths."

The following observation of a single meteor at Birmingham on the night of the 13th, together with a notice of the appearance of the shower as recently recorded there in previous years, was received from Mr. Wood:—

"December 12th, Meteoric Epoch.—Birmingham Observations.

"In 1866.—See the British Association Reports for that year.

"In 1867.—No observations; probably from bad weather, or impeded by moonlight.

"In 1868.—See the British Association Reports for that year.

"In 1869.—December 12th, a fine night; one meteor in half an hour, from radiant G.

"In 1870.—Overcast on the 10th, 11th, 12th, and 13th, excepting a clearance of an hour's duration from $11^h\ 30^m$ P.M. on the 12th to $12^h\ 30^m$ A.M. on the 13th. Five meteors in three quarters of an hour from radiant G, and traces of radiant K.

"In 1871.—December 12th and 13th, overcast, excepting half an hour from 11^h P.M. to $11^h\ 30^m$ P.M. on the 13th. Amount of clear sky = $\frac{1}{2}$. One meteor in this time from radiant M_1.

"December 13th, $11^h\ 12^m$ P.M.; third magnitude; blue; duration 0·5 sec. From κ Orionis; path 6°; directed from β Geminorum. Radiant M_1*.

At Buntingford, Herts, the only period clear enough for observations was obtained by Mr. Greg between $9^h\ 45^m$ and $11^h\ 30^m$ P.M. on the night of the 12th, the sky on the night of the 13th of December being completely overcast. Fourteen meteors were seen, of which thirteen radiated from the direction of Gemini. They were mostly small, with short paths and moderate velocities; scarcely more than two or three sufficiently bright to have attracted the attention of other observers at distant stations. The December star-shower appears to be no longer so striking, either in size or in number of the meteors, as it was eight or ten years since. The apparent velocities of the meteors were also scarcely greater than half, or perhaps about 40 per cent. less than those of the meteors of the August shower. The meteors noted by Mr. Greg were principally those which moved with short courses near the radiant-point. The backward prolongation of their tracks, projected upon a map, are closely clustered round the star θ Geminorum, which was the principal radiant-point, with a tendency also to be concentrated along a line of the meridian extending 5° or 6° north and south of that star, and principally southwards from it towards, and apparently nearly as far as, the stars ϵ and ν Geminorum, giving the radiant-region an oblong form, with its greatest elongation in the direction of an arc of the meridian.

At York the condition of the sky was so unfavourable that scarcely one meteor was visible during the whole of the December period. At Newcastle-on-Tyne the sky was also completely overcast. At Glasgow rain continued on the night of the 12th until ten o'clock, when the sky became clear, and remained so for an hour until about $11^h\ 30^m$ P.M., when it was again obscured. During this interval seven meteors from Gemini, nearly equal to first-magnitude stars in brightness, were recorded, and their apparent paths were mapped by Mr. R. McClure. The first (described in the above list of large meteors), which diverged like the rest from Gemini, was as bright as Jupiter; and but one meteor of the shower left a persistent streak. A Geminid was also observed at $12^h\ 20^m$ on the same night, and its apparent course was mapped. The tracks of all these shooting-stars prolonged backwards passed through a small circle about 12° in diameter, whose centre was close to the star ϵ Geminorum at a point in R. A. 97°, N. Decl. 28°. Twenty meteors were counted by two observers during the hour of the watch; but the paths of only the most conspicuous, which diverged from the direction of a radiant-point in Gemini, were recorded upon the map. On the night of the 13th, rain, and a completely overcast state of the sky, prevented any further observations.

By projecting all the recorded paths of the Geminids upon a single map, a

* This meteor may also possibly have been a "Geminid," the direction of its apparent path being very nearly conformable to the position of the radiant-point of the shower in Gemini as observed at its return last year.

radiant-region of oval form contained between the meridians of R. A. 96° and 112°, and between the parallels of north declination 20° and 40°, would include the directions of 37 of the 45 tracks which are thus drawn. In this area the intersections of the tracks, prolonged backwards, are slightly more concentrated than elsewhere within the radiant-space, at a point in R. A. 104°, N. Decl, 34°, about 4° from θ towards α Geminorum, while the general character of the radiation was diffuse; and the apparent paths of but few meteors were recorded near the radiant-point.

Meteor-shower of January 2nd–3rd, 1872.—On these dates a watch was arranged to be kept by observers in different places in England, and at Glasgow from half-past 10 o'clock until midnight; and a favourable view of the shower was obtained at most of them on the night of the 2nd of January.

Towards 11 o'clock a few detached clouds, which had partially obscured the sky in London during the earlier part of the evening of the 2nd of January, disappeared, and the view of the shooting-stars during the remainder of the watch until midnight was uninterrupted. In the neighbourhood of Regent's Park, Mr. T. Crumplen noted the appearance of nine meteors in this interval, beginning his watch at $10^h\ 45^m$, and recorded the apparent paths of six conformable meteors upon a map. Three of these were as bright as first-magnitude stars. All but one, which appeared ruddy, were white or bluish, not swift in their motion, and two of the brightest left a short streak of light upon their course. The courses of all, prolonged backwards, intersected each other within the space of a small circle 5° or 6° in diameter, having its centre at R. A. 228°, N. Decl. 52°. So quickly did bright meteors succeed each other, that it appeared probable that the shower would continue to be of some brilliancy after midnight. An aurora was visible at the same time in the north.

In the south-west part of London, near Eaton Square, the meteors were also watched by Prof. Herschel, between $10^h\ 30^m$ and midnight, the light of the rising moon, which first appeared at about $11^h\ 30^m$ P.M., being the only obstruction to their view. The paths of 16 shooting-stars were mapped, of which only one appears to have been unconformable to the usual radiant-point of the shower. It shot on a very short course close to Polaris from the direction of the zenith at $11^h\ 7^m$, and was not perfectly observed. Four or five smaller meteors may also have passed unrecorded. Six of the meteors mapped were as bright or brighter than 1st-magnitude stars, the brightest appearing white and those of lesser magnitudes of yellow colour. The brightest only of the meteors seen appeared to leave a faint streak of light, visible for less than a second, on its course. This meteor described a path of 35° in two seconds: it was as bright as Sirius during the last half of its course; it appeared at $11^h\ 56^m$, and its appearance was simultaneously observed at Hawkhurst. Of the fifteen conformable meteors, five were erratic members of the shower, their apparent paths, prolonged backwards, passing about 20° on each side of a very definite radiant-point, from which the remaining ten meteors all diverged. A circle of about 6° in diameter, round a central point in R. A. 227°, N. Decl. 49°, would include the intersecting prolongations backwards of the tracks of all the latter meteors. This apparent place of the radiant-point, which was close to that observed by Mr. Crumplen, is also not more than 5° from the position of the radiant-point of the same shower, at R. A. 234°, N. Decl. 51°, as observed in 1864 *. A slight increase in the rate of frequency during the watch appears to indicate a

* See these Reports for 1864, p. 98.

growing intensity in the progress of the shower, the numbers of the meteors recorded in the successive half-hours until midnight being 3, 5, and 8.

At Tooting, near London, the sky was also very clear on the evening of the 2nd; and Mr. H. W. Jackson noted the appearances of nineteen meteors between 10^h and 11^h P.M., the tracks of six of which were very accurately laid down upon a map. Eight meteors were observed; and the paths of two of them were mapped between 11^h and $11^h\ 15^m$, and only two meteors were visible in the following 15^m until $11^h\ 30^m$ P.M. The whole number of meteors seen by one observer in $1^h\ 30^m$ was 29. A bright meteor (described in the above list), whose course was exactly conformable to the usual radiant-point of 2nd of January shooting-stars, was also recorded by Mr. Jackson on the night of the 31st of December. Although proceeding generally from the direction of the radiant-region between Bootes and Draco, no definite centre of divergence was distinguishable among the meteor-tracks recorded at Tooting, which appear to have belonged to outlying members of the group; and one of the eight meteors mapped was unconformable to the general radiant-point of the shower. These meteors appeared for the most part white; they were generally bright, and left faint streaks upon their course, which remained visible upon the track of one of the brightest for about one second. A flash like lightning was observed at $10^h\ 16^m$ P.M., and two similar flashes were noticed between $10^h\ 16^m$ and 11^h P.M.

At the Royal Observatory, Greenwich, the apparent paths and appearances of fifteen meteors were registered between $10^h\ 12^m$ and $11^h\ 17^m$, of which four only were less bright than stars of the first magnitude, in a watch partly kept by one and partly by two observers. They were mostly bluish, but some yellowish white, and described apparent courses of from 10° to 40° in length, in one or two seconds of time. Ten of the meteors recorded in the list left more or less faint persistent streaks of light upon their course. Two or three of the meteors whose apparent paths were thus registered appear to have been unconformable to the general radiant-point, and the tracks of the remainder prolonged backwards present a space of somewhat diffuse radiation in the region about Quadrans and the tail-stars of Ursa Major.

The sky was also free from clouds at Hawkhurst on the night of the 2nd, and a watch for the January shower was kept from $11^h\ 20^m$ until midnight. Fourteen meteors were noted in this interval, and the paths of ten were satisfactorily observed, and were drawn upon a map. All were directed from the neighbourhood of the radiant-point in Quadrans; and the backward prolongation of their tracks presents a region of somewhat diffuse radiation, extending over an area about 25° in diameter, having an apparent principal centre of intersections at a point in about R. A. 220°, N. Decl. 47°. The meteors seen were principally of the first and second magnitudes, white, shooting across the sky in long courses, with moderately slow speed; and about half of their number left a slight persistent streak of light on the whole or on a part of their course. Several smaller meteors passed unrecorded, and the hourly numbers of the meteors seen was not less than twenty for two observers.

At Birmingham the sky was very clear on the night of the 2nd; the courses of fifteen or sixteen meteors were mapped; and the appearances of many more were noted by Mr. Wood during the hour between $10^h\ 15^m$ and $11^h\ 15^m$ P.M. At $10^h\ 17^m$ a flash like that of distant lightning (apparently the same as that recorded by Mr. Jackson near London, and if so, probably meteoric) was seen upon the south horizon during an interval of twenty minutes after 10 o'clock, in which no shooting-stars were visible. At

$10^h\ 20^m$ a meteor of fourth magnitude was seen, and at $10^h\ 21^m$ a sudden outburst of several bright varicoloured meteors made its appearance in all parts, four or five shooting-stars being visible in the space of an eye-grasp, so that it was impossible to record the particulars of more than one or two members of this group. Two of them noted by Mr. Wood were brighter than first-magnitude stars, leaving streaks, apparently not conformable to the usual radiant-point of the January meteor-shower, but rather diverging in nearly parallel courses from the radiant $A_{1,2}$ in Cassiopeia, or one of them possibly from the radiant NG in that neighbourhood. This burst of shooting-stars gradually subsided, and meteors as bright as first- and second-magnitude stars continued to succeed each other at short intervals until $10^h\ 49^m$, when intervals of meteoric quiescence, unbroken by the appearance of any shooting-star for 10^m, 14^m, and 20^m, succeeded each other; and the last meteors seen during the watch were recorded at $10^h\ 59^m$ and $11^h\ 13^m$ P.M. Among twelve meteors registered by Mr. Wood during the half hour between $10^h\ 20^m$ and $10^h\ 50^m$, two were as bright as, and five brighter than, first-magnitude stars, and five left luminous streaks that remained visible for two or three seconds on their course. In colour they were mostly blue, white, or yellow; and the duration of their flight was generally from one second to about one second and a half. Projected upon a map, the apparent courses appear to diverge from a centre between the last stars in the tail of Ursa Major and α Draconis, several of their visible tracks having been noted in or near the constellation Ursa Major; but many scattered meteors were observed; and in the following remarks on the shower Mr. Wood assigns various radiant-points to the principal meteors, whose directions he had projected and compared together upon the maps.

"*Meteoric shower of January 2nd*, 1872.—A fine shower of bright meteors, at the rate of twenty per hour for one observer, radiating in the proportion of 42 per cent. from K_1 [radiant of the annual shower],

22 „ from MG,

36 „ distributed over the radiants $A_{1,2}$, A_{16}, NG, DG_4, KG.

"Meteors of slow apparent speed, train-bearing, and varicoloured. The time of maximum, the duration, and intensity of the shower could not be ascertained in consequence of clouds supervening on the succeeding night. The foregoing meteors were probably only a fragment of the shower."

A description of the shower by Mr. J. Morton, at Eccles, near Manchester, was communicated to the Committee by Mr. W. F. Denning. It was first noticed at $8^h\ 40^m$ P.M. on the 2nd, the sky being then very clear, but afterwards becoming partially obscured by clouds. One bright meteor, leaving a train of sparks, and five smaller ones were seen before 9 o'clock; and eight meteors of some brightness from that time until $10^h\ 23^m$ P.M. Six of the fourteen meteors noted were as bright as second, and one was as bright as a first-magnitude star.

At Glasgow the sky was so hazy on the night of the 2nd, between $10^h\ 55^m$ and $11^h\ 20^m$ P.M., that Jupiter and the brightest fixed stars only were visible; but during the remainder of a watch from 10^h to 12^h P.M. the sky was generally clear, and fourteen meteors were observed in this interval by Mr. R. M'Clure. The apparent paths of nine of them were drawn upon a map; and of these meteors four were as bright as first-magnitude stars, two were as bright, and the rest fainter than stars of the second-magnitude. All but one, of reddish colour, which passed in a short course from Ursa Major across the star Pollux, appeared white; and they described arcs of from 5° to 20° in length, in times which varied from a half to a full

second in duration. Their tracks projected upon a map, although proceeding, as in the foregoing observations, from a general radiant-region near and around the star θ Bootis, presented within that space no well-marked centre of divergence.

On the same night, and during the morning of January 3rd, as appears from the following observations at York and Sunderland, the shower continued to be very bright, with occasional lulls and apparently outbreaks of its intensity, until near the approach of daylight. At Sunderland Mr. Backhouse reported that "though the night of the 2nd was for the most part very fine, yet at the appointed time the sky was so cloudy that I only watched for a short time, especially as meteors were so scarce. I only saw one at that time; but in the morning I watched for at least twelve minutes in a cloudless but moonlit sky, the radiant-point in Draco being high in the sky, yet I saw no meteor belonging to that system, and only one altogether. The evening of the 3rd was fine till about 10^h P.M., when it clouded over. I did not see a single meteor, though I watched for about ten minutes at $6^h\ 30^m$, and equally long about $9^h\ 15^m$."

Another considerable outburst of the shower must, however, have occurred shortly before daybreak on the morning of the 3rd, as the brilliancy and rapid succession of the meteors at that time at Street, Somersetshire, attracted a child's attention, who, as related by Mr. Clark, informed him of some of the particulars of their appearance. "The nights, both of the 2nd and 3rd, were so unfavourable as to prevent me from sending you any observations. On the *morning* of the 3rd, however, I had an account from my nephew, who though but eight years old is intelligent enough to take a good deal of interest in simple scientific things, of several meteors which he had seen, coming rapidly after one another, and evidently somewhat bright."

On the following evening, and night of the 3rd to the 4th of January, the sky was so completely overcast at all the British-Association stations that no shooting-stars could be observed; but on that evening a single meteor, as brilliant as Jupiter (as described in the above list), was observed at Greenwich, the direction of whose apparent course was almost exactly directed from the radiant-point K_3 in Quadrans (Bode, or in the region of Draco between Hercules and Bootes), which distinguishes the annually recurring meteor-shower of the 1st–3rd of January.

Meteoric showers of April, 1872.—Some observations of the April star-shower in 1871, not included in last year's Report, were obtained by Mr. Clark, at York, with a clear view of the sky, from shortly before ten o'clock until midnight on the night of the 19th of April in that year. Six rather bright meteors, with very short courses of only a few degrees in length near the constellation Ursa Major, were mapped, belonging apparently to the meteoric system or group of radiant-points M_4 in that constellation. One meteor from the direction of Lyra was also seen before eleven o'clock, and six between eleven o'clock and midnight, the sky being equally clear,—the numbers of meteors of all kinds seen in the former hour being six, and in the latter nine. The sky was overcast on the other nights of the shower.

The radiant-point M_8 of Heis's and Greg's former list* was marked in

* Report for 1864, p. 99. Radiant at R. A. 160°, N. Decl. 51°, enduring from April 16th–30th, apparently identical with M_8 of Heis's list for April, at R. A. 155°, N. Decl 47°, near λ Ursæ Majoris: now subdivided by Mr. Greg into separate radiant-points, MZ and MGZ, near θ Ursæ Majoris and Cor Caroli, in March and April; M_1Z near γ Leonis on the 19th–20th of April; and MG_1 in the Lynx, near the fore feet of Ursa Major, from the end of April to the beginning of June. (See the Table at the end of this Report.)

April last by the appearance of some conspicuously bright meteors, to whose characteristic brilliancy Mr. J. E. Clark drew particular attention in the following communication to 'Nature' of May 2nd, 1872 (the meteors alluded to by Mr. Clark are described in the foregoing list):—

"I noticed in your Number of last week the account of a brilliant meteor observed in Cumberland on April 19th. Now I had reported to me a very similar meteor at nearly the same time (about 8^h 40^m P.M.), an account of which I forwarded, with the other results of my night's watch, to Mr. A. S. Herschel, who would gladly receive any further report of the same; unfortunately I have not the Number of 'Nature' at hand, and therefore cannot make a personal application to your correspondent. On the same evening, about 11^h 7^m, I myself saw an exceedingly brilliant meteor, which fell to a point just south of Vega. It is curious that both of these came from the radiant situated at about R. A. 155°, N. Decl. 47°, or rather from one of the group of radiants there situated, M_8 of Heis, 56 and 52 of Schiaparelli. It would be an interesting point of investigation whether the meteors from that radiant-point are of peculiar brightness."—J. E. Clark, April 30th, 1872.

The meteor seen by Mr. Clark at York was seen at the same time at Hawkhurst; and the direction of its apparent path there, prolonged backwards, meets its similarly prolonged track, as observed at York, near χ Ursæ Majoris, very near the position of the radiant-point M_8. The bright meteors described in the above list on April 5th and 19th, and May 3rd, appear all to have diverged from the same group of meteor-radiants in Ursa Major. Those recorded on March 26th, April 12th and 22nd, radiated from centres of a group of apparently equally bright meteor-showers, $S_{4,5,6}$, in the neighbourhood of Virgo and Comæ Berenices.

On the evenings of the 12th, 13th, and 14th of April, 1872, Mr. Greg watched at Buntingford, Herts, for an early appearance of the April meteor-showers from the direction of Cerberus or Lyra (QH_1, QH_2), connected together apparently in one meteor-system making its appearances on the 13th and 19th–20th of April. The former radiant-point was noted from the paths of nine small shooting-stars, seen in about two hours on the morning of the 13th of April, 1864, by Prof. A. S. Herschel at Hawkhurst*; and no appearance of this shower appears to have been again visible in subsequent years. Its radiant position at R. A. 270°, N. Decl. 25°, was yet distinctly marked, the meteors resembling each other even more closely than those of the group from Lyra in their appearance, and moving in swift courses over all parts of the sky from a region of somewhat diffuse radiation, extending to but not exceeding the limits of the small constellation Cerberus (Bode), with an average centre at about the position named. By its close neighbourhood to the well-established radiant-point of the Lyraids at about R. A. 278°, N. Decl. 34°·5 †, it appears to have been an early commencement of that shower, and an integral part of the meteor-system which was first shown by Drs. Weiss and D'Arrest to be apparently connected with the periodic orbit of the Comet I, 1861. Mr. Greg's watch for the early reappearance of the group on the above date was unsuccessful, two small meteors only being observed from the radiant DG (in the head of Draco), and two meteors radiating from the direction of β Herculis, during a very careful watch on each of the above-named nights.

Shortly after the end of April last, a communication from Mr. W. F. Den-

* Report for 1864, pp. 40 and 98.

† See these Reports for 1864, p. 98, and 1868, p. 399.

ning informed the Committee that Mr. Knobel, at Burton-on-Trent, had observed "many meteors in April, particularly on April 14th, 1872. They appeared to radiate from a point in Bootes east of ζ Bootes." This point, which is very near to β Herculis, was nearly in the direction of the last two meteors seen by Mr. Greg, and in the position of the general radiant $Q_{1,2}$* of meteors first beginning to be seen about the 23rd of April, but which appears from these observations to present itself close to the same position at least ten days earlier, on about April 12th. (See the Table at the end of this Report. Radiant, No. 51.)

The night of the 19th of April, 1872, was generally not unfavourable for observations at most of the British-Association stations. At York, until nearly 11^h P.M., the sky was nearly overcast; but at that hour the clouds began to disperse, and soon after the beginning of the watch they had finally disappeared. During the succeeding interval between $10^h\ 45^m$ and $11^h\ 45^m$ P.M. nine meteors, two of them as bright and two brighter than first-magnitude stars, were observed, six being visible in the first and only three meteors, with two or three faint flashes near α Lyræ, in the last 45^m of the watch. From 11^h to $11^h\ 15^m$ there seemed to be quite a brisk shower, but after that time their rate of fall diminished considerably. The Lyraïds were all noticeably rapid in their flight, their courses varying from 5° to 25° in length, and the duration, even of the longest, scarcely exceeding half a second. They were colourless or white, and there was a noticeable absence of streaks upon their course. Two or three meteors diverged from a radiant, No. 53 of Schiaparelli, in Comæ Berenices, apparently connected with the radiant $S_{1,5}$, near the same constellation, in Virgo, of Heis; others from M_8; and five of the nine shooting-stars whose courses were mapped were Lyraïds. The brightest of these appeared at $11^h\ 28^m$, and its apparent course was also noted at Wisbeach and at Hawkhurst. The radiation of the Lyraïds was not very exact; but the courses of three, prolonged backwards, intersected each other very nearly at a point in R. A. 280°, N. Decl. 43°, near π Lyræ. Some further observations on the progress of the shower will shortly be given from Mr. Clark's report of its appearance.

At Buntingford a clear sky prevailed on the 19th, between $11^h\ 15^m$ and $12^h\ 45^m$, and the apparent paths of seven meteors of first and second magnitudes, all of them meteors of the April shower, were drawn upon a map by Mr. Greg. The backward prolongation of their tracks, which were generally not far from the radiant-point, presented a very definite area of intersections 3° or 4° in width, at about R. A. 268°, N. Decl. 25°, in Cerberus. Their courses were generally short; and the following is Mr. Greg's description of their appearance:—"Owing to the moon being so bright the tracks were rendered rather shorter and the trains less visible than they would otherwise have been, besides causing me, no doubt, to miss seeing a number of others. Certainly there was distinctly a shower going on which was not visible on the evenings of the 12th, 13th, and 14th. Five only of the seven were very white; their average brightness was that of a first- or second-magnitude star, and owing to the shortness of their apparent paths their duration was *under*, if any thing, half a second. The radiants QH_1 [of meteors on the 12th–13th, in Cerberus] and QH_2 [of the Lyraïds on the 19th–20th of April] appear to me to be simply one and the same shower, with a slight difference in the dates and in the positions of the radiant-points." The sky was quite overcast at Buntingford on the night of April 20th.

At Mr. Crumplen's station in London the sky was remarkably clear, but

* Report for 1868, p. 402.

only three meteors radiating from near α Lyræ, and in the neighbourhood of that constellation, were observed in a watch of three quarters of an hour, at about 11 o'clock on the evening of the 19th. The first of these was as bright as a first-magnitude star, leaving a streak of light upon its course which remained visible for nearly a second. On the night of the 20th, soon after 10 o'clock, the sky was entirely overcast.

At Bristol, on the 19th, few stars were visible between 10^h and 11^h, the sky being very cloudy, excepting for a few minutes in the north-east, at about eleven o'clock, when one conspicuous meteor and one small one only were seen by Mr. Denning. The former rather bright meteor is described in the above list.

At Birmingham a hazy state of the sky also prevailed on the 19th, and strong full-moon light on this and the following evenings only permitted a single meteor to be seen. The scarcity of meteors on the latter night during an hour's attentive watch was, however, fully confirmed by the other observations which will shortly be described.

"*Meteor shower of April* 1872.

"April 19th, from 10^h P.M. till 11^h P.M. Sky hazy; moonlight; no meteors.

" 20th; from $10^h\ 20^m$ to $11^h\ 20^m$ P.M. Sky clear; moonlight; one meteor.

" 20th, $10^h\ 59^m$ P.M.; brighter than a 1st-mag. star; white; duration 0·5 second. From α Aurigæ; path 10°, directed from α Lyræ. Left no streak (a part only of the meteor's course seen, askance)."—*W. H. Wood.*

On account of the overcast state of the sky no observations on these dates were obtained at either Glasgow, Newcastle-upon-Tyne, or Sunderland.

A list of six meteors seen at Wisbeach between $10^h\ 45^m$ and $11^h\ 30^m$ P.M. on the 19th, with a tracing of their apparent courses on a map, was received from Mr. S. H. Miller, with the following remarks on their appearance:—"There was a remarkable accordance in their direction, and No. 6 seemed to take the same path as No. 5. The brightness of the moon interfered with the observations of their colour, and also of the length of their path, especially as they were small, and their trains of light a thin streak. I did not see one on the 20th, although I kept a persistent watch." In reply to a later inquiry on the latter point, Mr. Miller adds, "The sky was clear on the night of the 20th, during the hour I watched, and had there been any meteors then, I think I must have seen them; but after $11^h\ 30^m$ it became cloudy, and there was rain on the next morning early."

On the night of the 19th, at Hawkhurst, the sky was very clear, the moonlight bright, and a faint aurora was visible in the north. Between 11 o'clock and $12^h\ 15^m$, four observers counted 16 meteors, whose apparent courses were more or less exactly recorded. Ten of these meteors were seen in the first, and six in the last half of the watch, and nine were as bright as, or brighter than, 1st-magnitude stars. Two of the brightest meteors mapped were also simultaneously observed at York, and one of them diverging from Lyra was at the same time recorded at Wisbeach. Nine of the sixteen meteor-tracks were directed with no distinct centre of radiation from a space between α Lyræ and δ Herculis, and the remaining meteor-tracks were nearly equally distributed in their directions from the radiant-points WG (?) in Cygnus, $S_{4,5}$ in Virgo and Comæ Berenices, $Q_{1,2}$ in Corona, and M_8 in Ursa Major.

The only meteor from the latter radiant-point (near the zenith) was the very brilliant one seen to fall vertically elsewhere, and described as proceeding from the same radiant-point by Mr. Clark, at York. The Lyraïds appeared white and swift, and generally left no streak; but when seen foreshortened near the radiant-point they sometimes appeared bluish or yellowish, and left persistent streaks. The sky was overcast on the night of the 20th, and no meteors were observed.

At the Royal Observatory, Greenwich, during an interval of clear sky on the 19th, between half-past ten and half-past eleven o'clock, six meteors were registered by one observer of Mr. Glaisher's staff, of which three were as bright as first-magnitude stars, and four diverged from the neighbourhood of α Lyræ. The Lyraïds were all bluish white, with short apparent paths, leaving streaks. On the night of the 20th, the sky at the Royal Observatory, Greenwich, was too cloudy for further observations of the April shower.

During the night of the 19th of April, it appears, from observations which were continued at the Radcliffe Observatory at Oxford, by Mr. Lucas, until the appearance of daybreak, that the activity of the April meteor-shower was very brightly maintained until the morning of April 20th. During a strict watch kept for shooting-stars on that morning from 1^h A.M. until 4^h A.M., the sky was quite clear during the first hour, and only crossed occasionally by clouds from the south-west during the last two hours of the watch. Towards 4 o'clock A.M., the brightness of the full-moon light gave way to that of the approaching dawn; and a thick haze beginning at this time to overspread the sky, at length obscured all but a few stars of the first and second magnitudes. The appearances of twenty-six meteors were recorded; five in the first, five in the second, and sixteen during the last hour of the watch; the numbers of 1st-magnitude shooting-stars visible in the same times being two, one, and six. Seventeen of all the meteors noted were Lyraïds, of which the numbers recorded during the same times were four, three, and ten. Six of the Lyraïds were as bright as first, and six as bright as second-magnitude stars, and they appeared white even in the strong moonlight. Their courses were generally very rapid, sometimes 20° or 30° in length, and occasionally leaving a persistent streak. Of the nine remaining meteors, all but two proceeded apparently from a radiant-point in Cygnus eastward from that in Lyra, not far from the position in May and June of a radiant-point WG in that constellation; four courses prolonged backwards intersect each other close to ϵ Cygni, near which one of these unconformable meteors also moved with a short apparent path. The brightest meteor seen during the watch moved from the direction of ϵ Cygni, bursting when it had reached the brightness of Jupiter, on a long course from γ Cassiopeiæ nearly to Capella; its duration was two seconds, and it was followed by the next meteor, which appeared as bright as a 2nd-magnitude star, moving upon exactly the same course. Two other unconformable meteors were directed from the radiant-points $S_{1,5}$ in Virgo and Comæ Berenices.

The tracks of the seventeen Lyraïds, prolonged backwards, all passed through a region of radiation including the chief stars of Lyra and the stars ξ, o Herculis, where a circular area, about 15° in diameter, with its centre at R. A. 275°, N. Decl. 32°, would include all the directions of the Lyraïds that were observed, and was probably very near the central point of divergence of the group. The radiant-point being near the zenith when the Lyraïds were most numerous in the last hour of the watch, and their courses extending round it towards all parts of the sky, this apparent place of the radiant-point,

although not definitely marked by exact intersections of their apparent paths, yet appears to be the best average position of the somewhat diffuse centre of divergence which they appear to have presented that was obtained during the last annual reappearance of the April meteors.

The notable absence of meteors on the evening of April 20th, after the somewhat considerable star-shower that was seen at most of the stations on the preceding night, was especially remarked by Mr. Clark, who described the following particulars of the watch which he kept at York for the appearance of any continuation of the meteor-shower which might be visible on the second night:—"The watch on Saturday the 20th was altogether unsuccessful. I commenced a few minutes before 10^h, and was joined at $10^h 25^m$ by Mr. Brown, when for about ten minutes a cirrus cloud from the east obscured two thirds of the sky, and we were driven in by a snow-storm from the north at $11^h 10^m$; after which I did not watch, as it remained more or less cloudy. However, during that period of nearly an *hour and a quarter*, for half the time *two watching*, we did not see with certainty *a single meteor*. Such a remarkable absence of them I have never noticed before. To be sure the moon was brilliant, but not so brilliant as to obscure 4th-magnitude stars."

Meteoric Shower of May 1872.—Some preparations which were made by the Committee to watch for the appearance of any star-shower or conspicuous meteors on the nights of the 17th, 18th, and 19th of May, when such have been occasionally observed, were entirely frustrated by a constant succession of wet and cloudy weather. During the hour appointed for observation on the evening of the 20th of May, Mr. Miller watched, with a tolerably clear view of the sky, at Wisbeach, without seeing any meteors.

A single bright meteor of the shower was seen at Newcastle-on-Tyne, in an interval of clear sky for about twenty minutes, on the night of May 17th–18th, at $12^h 10^m$ (midnight) by Professor Herschel. It resembled α Lyræ in brightness and colour, and passed in two seconds from between ζ, η Draconis to between ζ, η Ursæ Majoris, beginning its course 5° before, and ending it 5° beyond those stars, and leaving a bright streak upon its whole track, which remained visible, even in the bright moonlight, for one or two seconds. The meteor's motion was apparently from the radiant DG_2 in Draco, and was not conformable to the principal radiant-group in Corona and Hercules ($Q_{1,2}$) of this meteoric epoch.

Papers relating to Meteoric Astronomy.

A pamphlet of printed instructions to observers of shooting-stars for the year 1872–73 has been circulated among astronomers and the associated observers of shooting-stars in Italy by Professor Schiaparelli and Signor F. Denza, appointing five or six nights in each month for combined observations, together with a list of nights in the whole year for which not more than twenty meteor-tracks were recorded by Zezioli. Observers at fourteen Italian stations are engaged in these observations; and the Italian Luminous Meteor Association have already recorded the apparent paths of 6151 meteors in 1870, and of 10,257 meteors in 1871, which have been projected upon suitable maps for exhibiting the radiant-points which they present. It is intended to print these maps so as to exhibit the positions and characters of the different radiant-points, with their dates of appearance, as clearly and conveniently as possible to the eye. The star-maps employed by the Association of Italian observers are constructed upon the same projection as the well-known Celestial Atlas of Professor Dorna of Turin. The observations

of shooting-stars made at the observatory of Moncalieri continue to be published in the Meteorological Bulletin of that observatory, in which nearly 1000 meteor-paths observed before the end of April 1869 have been already published. All the observers' notes are also transmitted to Milan for final reduction and arrangement in a collective Catalogue by Professor Schiaparelli.

In connexion with this extensive research, an enlarged edition of his original Memoir on the Astronomical Theory of Shooting-stars* has recently been compiled by Professor Schiaparelli, and was published last year under his directions, as a separate volume, in the German language by Dr. von Boguslawski, of Stettin†. The materials of the original Treatise have been much increased, so as to present a full account of the recent investigations in meteoric science whose results have most contributed to advance this modern branch of astronomy since the publication of his former work. A complete Table of all the 189 radiant-points obtained from Zezioli's observations‡, the full particulars of which have not been previously published, is also embodied in the work, with a supplementary Table showing the position of each radiant-point with regard to the apex of the earth's way, and the principal elements of its parabolic or cometary orbit. In a list of notes on the several radiant-points, a comparison of their positions with those obtained by other observers, showing them in many cases to corroborate or to correct former observations, is made to connect the new list of radiant-points in every important point of agreement with the older lists of Heis, Greg, and Schmidt, and with the separate determinations of special radiant-points by individual observers. A useful summary of these results is given by Mr. Greg in the accompanying comparative Table of radiant-points, presenting in one view all the points of difference and resemblance between the several general catalogues of radiant-points which have hitherto been published, with the exception of the extensive Catalogue recently printed by Dr. Schmidt in the second volume of the publications of the Observatory of Athens, to which the Committee have not yet been able to refer §. With the aid of observations received since the appearance of the last printed Meteor-Catalogue in these Reports, the Committee propose to consider more closely the epochs and positions of the general radiant-points exhibited in this Table, and to enter in a future Report into a complete discussion of the identity and of the comparative importance of the different families or groups of meteoric showers which, in many instances, it appears most properly to represent.

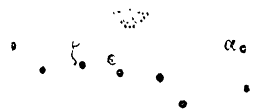
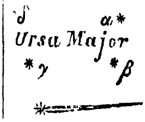
* "Note e Reflessioni intorno alla Teoria Astronomica delle Stelle Cadenti." (See these Reports for 1868, p. 407.)

† Entwurf einer astronomischen Theorie der Sternschnuppen, von. J. V. Schiaparelli. Aus dem Italienischen übersetzt und herausgegeben von Georg von Boguslawski (8vo, with four Plates, 268 pp.). Stettin, 1871, Verlag von Th. von der Nahmer.

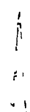
‡ A Table of the principal meteor-showers only of this later list was formerly published by Professor Schiaparelli (*vide* Report for 1870, p. 98), with slight subsequent alterations in two Memoirs in the Ephemerides of the Milan Observatory, containing annotations on the history and characteristics of each meteor-shower of the List, one memoir including the meteor-showers observed in each half year. That for the first half year was noticed in the last Report (1871, pp. 44-48), and the concluding Memoir has since been received by the Committee from Prof. Schiaparelli. To this complete cycle of meteor-showers, and to the descriptive notes which it contains, further consideration will be devoted in the next Report.

§ The same Table is also presented by Dr. Schmidt in the 'Astronomische Nachrichten,' No. 1756.

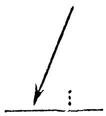
GENERAL LIST OF BOLIDES AND

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position.
1783. Jan. 8	h m s Evening ...	Slough, Bucks...	Very bright.........	Very white ...	....	....
Sept. 26	....	Ibid	Brilliant	....	....	Passed along close under α Lyræ.
Nov. 2.	8 55 p.m.	Ibid	Large and bright...	....	....	Dropped from δ Cygni.
1794. June 28	3 55 a.m.	Ibid	Rocket-like	....	Meteor-streak.  Ursa Major.	
1871. Sept. 1	10 45 p.m.	Knocklong, Co. Limerick.	Very brilliant	....	....	In the southern sky at an elevation of about 20°.
10	10 48 p.m.	Knocklong, Co. Limerick.	Very bright.........	Showed most beautiful colours.	....	First visible near Pegasus and passed across the sky to Capella.
17	10 7 p.m.	Between Aldershot and Farnham.	Fully as bright as Venus.	....	Slow and stately motion.	α= δ= From 328°+17° to 300− 2½, ending its flight a little beyond θ Aquilæ.
Oct. 8	10 28 51 p.m.	Regent's Park, London.	Nearly as bright as Venus.	White	Slow motion. .	From altitude 45°, 15° W. from S., to altitude 30° or 35°, 20° W. from S.
11	About 12 7 or 12 10 a.m.	Brompton, London.	Very large	Intensely vivid green.	Two or three seconds.	By the side and to the north of Jupiter; about as far from him as Castor is from Pollux.
11	9 5 50 p.m.	Royal Observatory, Greenwich	Brighter than Jupiter.	Bluish; the fragments crimson.	6 seconds. ...	Moved from Polaris in a nearly straight line between ε and ζ Ursæ Majoris.
Nov. 9	11 56 10 p.m.	Ibid..............	Brighter than Jupiter.	Bluish	6 seconds. ...	Passed between γ and ε Leonis.
11	8 17 30 p.m.	Ibid..............	Twice as bright as Jupiter.	Bluish-white .	1 second......	From near the Pleiades, passed close to γ Tauri about halfway between α and λ Tauri.
12	7 45 p.m. (Possible error 2m.)	Tenby, South Wales.	Brighter than the fixed stars.	Orange-yellow	2 or 3 seconds. Slow motion.	Course as in sketch. 

BRIGHT METEORS OBSERVED IN 1871 AND 1872.

Length of Path.	Direction.	Appearance; Remarks, &c.	Observer.
....	Fell perpendicularly to the horizon.	Globular nucleus. Left a streak visible 40^s after the meteor had disappeared.	Sir W. Herschel's MS. Journal.
....	....	Gave a very bright light. Left a luminous streak visible for 1^m 20^s or 30^s to the eye, and for about 3^m in the telescope finder.	Id.
....	Course parallel to κ and γ Cygni	....	Id.
....	....	Resembled a faint sky-rocket. A portion of the train in the position shown in the sketch remained visible for 3^m at least.	Id.
20°	Horizontal from east to west.	....	Jerem. Hedly.
Long course...	....	Several other meteors were seen on the same night, but none so conspicuously brilliant as this one.	Id.
....	Directed from Andromeda......	Disappeared gradually; left a long, broad, blue streak for 4 or 5 seconds. A clear night; and a few lesser meteors were occasionally visible.	T. Crumplen.
....	Path curved. 	The sky was too cloudy to verify these positions by the stars.	G. J. Symonds.
....	Dropped straight down	Increased in size gradually, and at length became club-shaped, as in the sketch. A magnificent meteor. The green colour *most brilliant*. 	H. W. Jackson.
35°	....	Increased gradually; burst into six or seven fragments, the last two of which were of a fine crimson red colour; left a bright, very enduring streak.	William Marriott.
25°	Directed from μ Ursæ Majoris	Nucleus increased as it advanced; and at last burst into several fragments, some of which were crimson.	Id.
20°	....	Left a slight streak.....	W. Bishop.
About 10° or 12°.	....	At first a faint streak; increased gradually, and disappeared suddenly, with the appearance of sparks. Left no conspicuous streak.	T. W. Webb.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position.
1871. Nov. 13	h m 9 5 p.m.	Newcastle-on-Tyne.	Much brighter than Venus.	White; no other colours.	....	Apparent path about 10° S. from West, reaching to the horizon.
13	11 25 p.m.	Beckenham, Kent.	Large	Reddish	....	Across the lower part of Ursa Major.
15	5 45 p.m.	Regent's Park, London.	Brighter than the fixed stars.	Ruddy colour.	Moved slowly.	$\alpha=$ $\delta=$ From 240°+66° to 197+74
15	8 34 p.m.	West Hendon, Sunderland.	Brighter than Venus.	....	....	Shot from Algol towards ν Tauri, disappearing a few degrees before reaching λ Tauri.
19	10 44 p.m.	Royal Observatory, Greenwich.	Brighter than Jupiter.	White	3 seconds......	Course near and parallel to Orion's belt.
Dec. 6	8 14 p.m.	Birmingham ...	As bright as Venus at its maximum.	Blue...........	$1\frac{1}{2}$ second ...	$\alpha=$ $\delta=$ From 97°+50° to 76 +17
6	8 15 p.m.	Beeston, near Nottingham.	Very large	Red	....	Shot from β Aurigæ towards α Tauri, disappearing at a point in R. A. 5^h 10^m, N. Decl. 31° 30′.
12	10 39 p.m.	Glasgow	As bright as Jupiter	White	0·75 second...	....
20	10 28 p.m.	Nancy, France...	Large	Green	....	From Cassiopeia, through Perseus, towards the Pleiades, near to which star it disappeared.
31	About 10 25 p.m.	Tooting, near London.	Brighter than Jupiter.	....	1 or 2 seconds	Shot across q and π Orionis. $\alpha=$ $\delta=$ From 73°+13° to 69 + 4

Length of Path.	Direction.	Appearance; Remarks, &c.	Observer.
About 25° ...	Obliquely down, as in this sketch.  West horizon.	Left a very bright, enduring streak on a part of the latter portion of its course. [Seen also at York, where it appeared not to be directed from Leo, but from a radiant-point distant from it by a few degrees.—E. Clark.]	H. Page.
....	Shot horizontally from east to west.	Left a long train. [Seen also at Norwood, Kent, moving from E.N.E. to W.S.W. In a watch of two hours on the same night meteors appeared to be unusually scarce.—*Id.*]	The 'Standard.'
....	....	Nucleus appearing to rotate in its flight, leaving some streaks and a long train upon its course. Disappeared gradually, without explosion.	T. Crumplen.
....	....	As bright as Venus during most of its course, growing suddenly brighter just before disappearance. Left a short streak for 2^s at the middle of its course, at N. Decl. 21°.	T. W. Backhouse.
....	Directed from α Ceti	Left a fine streak. End of the meteor's course not seen.	W. C. Nash.
....	From radiant K G	Meteor increased in size, and collapsed at maximum; leaving a transient train on its course.	W. H. Wood.
....	[From radiant M_1 (or K G?)]	Exploded with a bright flash. Left some luminous red sparks on its track, and a bright train of red points, which remained visible for about three minutes.	E. J. Lowe: 'The Times,' Dec. 8th.
....	....	Left no streak. [At Bristol Mr. Wm. F. Denning observed a large meteor at $9^h\ 42^m$ pass downwards in the west. No stars were there visible to record its path.]	R. M'Clure.
....	....	At disappearance the meteor burst, with a bright green flash. [The radiants observed in France during this month appear to confirm very closely Dr. Heis's previous results.—M. Faye.]	P. Guyot: 'Comptes Rendus,' Jan. 15, 1872.
Short course..	Almost vertically down	Increased in size, and disappeared with a slight explosion. The course may have extended onwards a few degrees beyond the stars named. 	H. W. Jackson.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position.
1872. Jan. 3	h m 8 13 ±	Royal Observatory, Greenwich.	= Jupiter...........	Bluish white .	More than 1 second.	From centre of Auriga, passed half way between β Tauri and ι Auriga, across Aldebaran, and about 10° beyond.
8	About 11 p.m.	Sutton	Large	....	....	First appeared in the N.W. and passed across the western sky about halfway between the horizon and the zenith.
Feb. 19	10 20 p.m.	Brompton, London.	Brighter than Jupiter.	....	....	Appeared near Regulus, and passed across a point about $\frac{1}{3}$ of the way from α Hydræ to Sirius.
19	10 21 p.m.	Royal Observatory, Greenwich.	....	Bright light blue.	3 seconds......	From a point nearly midway between Procyon and Sirius moved nearly parallel to Procyon and α Orionis.
Mar. 26	7 55 p.m.	Bedford	= Jupiter...........	Orange..	....	From $\frac{1}{2}$ (η Ursæ Majoris, γ Boötis) to very near β Cephei.
April 1	12 9 a.m	Barnsbury. [Seen also at Ray-Lodge Observatory, Maidenhead, by Mr. Lassell and Dr. Huggins.]	At first small, then large and bright.	First white, then red, then intense purple.	Not more than 1 second.	From R.A. 6^h 40^m, N. Decl. 33°, to R.A. 9^h, N. Decl. 0° (point of disappearance).
1	8 30 p.m.	Radcliffe Observatory, Oxford.	Three times as bright as Jupiter	Green	....	Appeared at an altitude of about 30° under Cassiopeia, and disappeared behind tall houses.
5	7 37 p.m.	Upton Helions, Crediton, Devon.	As bright as Jupiter or Venus.	White, with a tinge of green.	About 5 secs. .	Descended from about 15° to about 5° above the N.W. horizon.
12	10 45 p.m.	Somerset House, London.	= Jupiter...........	White, with red sparks.	$2\frac{1}{2}$ seconds ...	Passed between p and r Lyncis from the direction of t (near δ) Leonis, disappearing 6° or 8° beyond those stars.

Length of Path.	Direction.	Appearance; Remarks, &c.	Observer.
35°	[From Jan. 2nd radiant-point K_3.]	Left a fine streak	W. C. Nash.
....	....	....	'The Surrey Advertiser.'
....	....	Its whole course seen through thin clouds, which partly obscured Jupiter and Regulus. The point of disappearance is perhaps in error 5° or 6°. A very bright meteor.	H. W. Jackson.
15°	....	Left a streak. Sky hazy, lunar halo.	W. C. Nash.
....	....	Left a long, persistent streak on its course.	T. E. Elger: 'Astronomical Register,' May 1872.
....	....	Presented no extraordinary appearance at first, but increased in size and brilliancy to disappearance, illuminating all that part of the sky. End of its course hidden by a house. Only two other small meteors (moving from the same radiant-point towards α Tauri) seen between $11^h\ 40^m$ and 13^h.	F. W. Levander: Ibid.
....	....	[On the previous evening, March 31st, a very brilliant meteor was seen at Ray-Lodge Observatory, Maidenhead, by Mr. Lassell and Dr. Huggins, which lit up the whole sky.]	Mr. Keating.
10°	Fell vertically	Seen against the bright background of the sunset sky, while looking for the planet Mercury.	S. J. Johnson.
30°	From radiant $S_{4,5}$, near δ Virginis.	Nucleus followed by a short tail of red sparks, which remained visible when the meteor disappeared. Left no streak.	A. S. Herschel.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position.
1872. Apr. 19	h m s 8 30 p.m.	Greystoke, Cumberland.	Large apparent disk	Nucleus white, surrounded with bluish light.	Slow and regular speed.	Descended in the S.E., and disappeared before reaching the ground.
19	About 8 40 p.m.	York	Brighter than Venus.	....	About 4 secs., appearing to move faster at last.	First appeared slightly above the moon; disappeared behind some houses at an altitude of about 20°.
19	11 7 p.m.	York	Twice as bright as Venus.	Red and purple. At last white with red sparks.	$2\frac{1}{2}$ seconds ...	$\alpha=$ $\delta=$ From 215° +41° to 265·5 +30
19	11 7 30 p.m.	Hawkhurst	Brighter than 1st-mag. *	Yellow	0·5 sec. while in sight.	$\alpha=$ $\delta=$ From 330° +55° to 335 +45
22	10 13 p.m.	Wisbeach, Cambridgeshire.	Brighter than a first-magnitude star.	Yellow.........	3 or 4 seconds	$\alpha=$ $\delta=$ From 168° +62° to 22 +76 From Ursa Major to Cassiopeia.
30	7 52 p.m.	Radcliffe Observatory, Oxford.	Three times as bright as Jupiter.	Yellow	....	Began 15° or 20° E., and in a line with the pole. Disappeared at an altitude of about 15° above the horizon.
May 3	9 25 p.m.	Gateshead, Durham.	As bright as Jupiter	White, then orange-red.	5 secs.; slow motion.	From 2° north of ϵ Comæ Berenicis to 5° beyond a point 1° S. of τ Virginis.
28	12 0 midnight.	Regent's Park, London.	Larger, but not brighter than Venus.	Orange colour	Very swift ...	From a point 15° south of the zenith to 7° or 8° below Arcturus.
July 22	Between 8 30 p.m. and 9h p.m.	Near Chelmsford, Essex.	Like the moon ...	White, with other colours in its train.	About 2 secs. .	From alt. about 40° S.W. to alt. about 30° W.N.W. (rough estimation of position more than half way from the horizon to the zenith).
22	8 55 p.m.	Dunmow, Essex.	Brilliant	Front globe white; the rear one bluish.	....	Shot across the sky, about 5° to N. of Arcturus.

Length of Path.	Direction.	Appearance; Remarks, &c.	Observer.
....	Fell vertically	Nucleus globular, surrounded at last by flickering radiations. Disappeared without explosion. Left no sparks nor luminous streak. Sky hazy, with a lunar halo.	T. Fawcett: 'Nature,' April 25th, 1872.
33°	Descending with a slightly eastward slope.	Increased from a first-magnitude star to beyond the brightness of Venus. Left a transient train. Estimated path ... From $\alpha = 172°$, $\delta = +10°$ to $188{\cdot}5$, $-19{\cdot}5$.	Communicated by J. E. Clark.
20°	Directed like the last meteor, from radiant M_4 near η Ursæ Majoris.	Disappeared with some quickly extinguished sparks. The sparks left upon its course appeared to follow the meteor. Very brilliant even in the moon's light.	J. E. Clark.
5°..............	Fell vertically	Left a short sparkling streak, which advanced along the meteor's course, and appeared more conspicuous than the head. Last 5° of the meteor's flight only seen.	Miss M. R. Herschel and Miss J. Herschel.
50°	[From radiant M_4 in Ursa Major.]	A beautiful meteor, even in bright moonlight. The streak appeared to brighten up after the disappearance of the nucleus.	S. H. Miller.
....	Descended at an angle of about 45° towards the N.W. horizon.	....	Mr. Keating.
30°	Fell vertically from the direction of Ursa Major.	White in the first, and red in the last half of its course; broke at last into two or three red sparks, which immediately disappeared. Left no streak.	A. S. Herschel.
....	....	Nucleus kite-shaped; disappeared gradually, left no streak. Seen among clouds which partially covered the sky.	T. Crumplen.
About 40° ...	Descending with a slight slope.	Pear-shaped, leaving some sparks in its course. Disappeared without bursting.	T. Usborne.
....	S.E. to N.W.	The meteor displayed two globes of light, and appeared to burst at a great elevation.	H. E. Cockayne.

Experiments on Surface Friction.

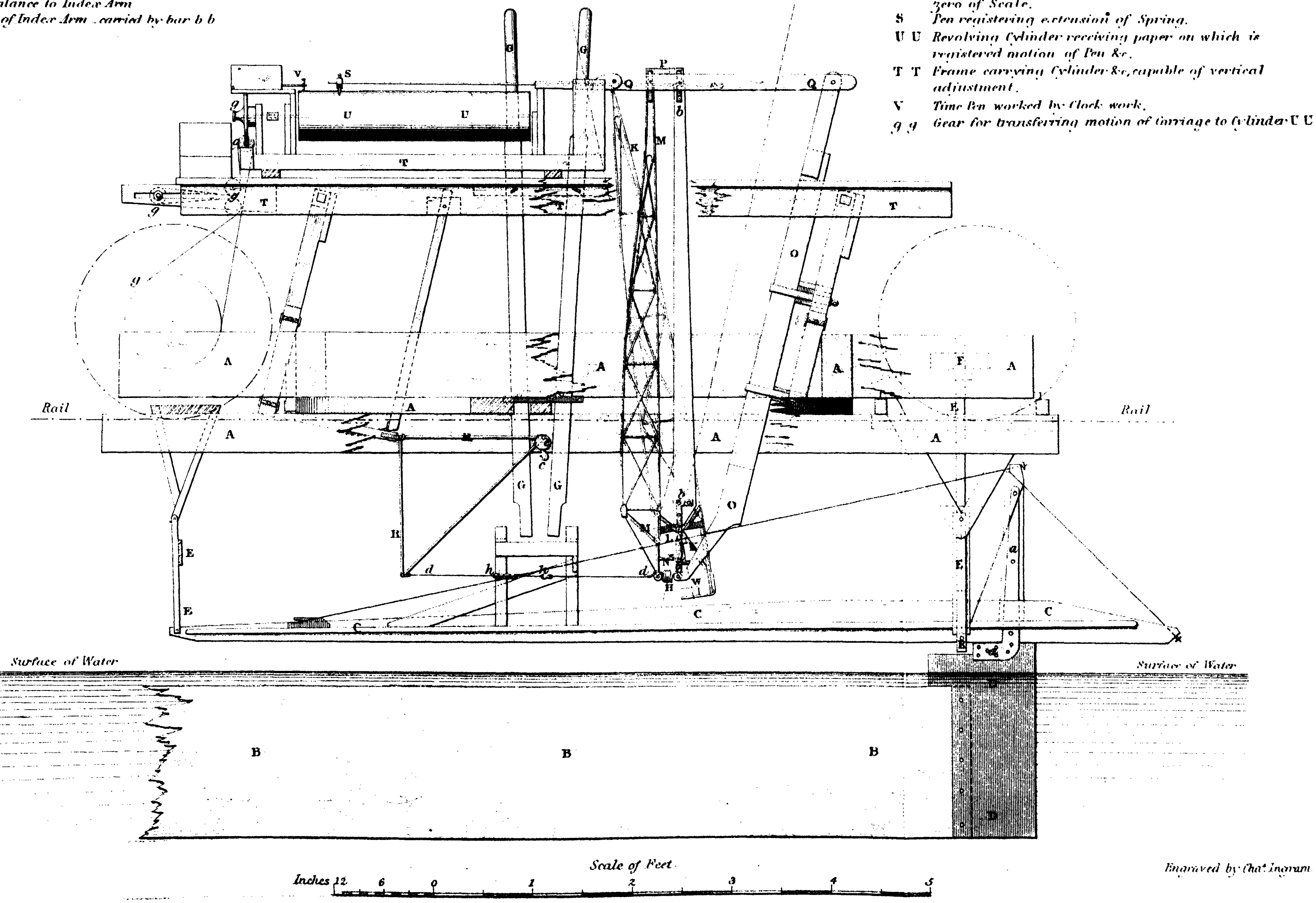
Dynamometric Apparatus.

REFERENCES.

A A Bed of Carriage
B B Plane, the surface friction of which is to be recorded
C C Horizontal Beam carrying Plane, and transmitting resistance of the same to spring, by means of Looped Connecting Line h h
D D Cutwater fixed to Beam C C by horns a a
E E "Parallel motion" supporting Beam C C
F Counterbalance to Beam C C &c
G G Lever arrangement for steadying the apparatus (taking the strain off the spring) while uniform speed is being obtained
H Spring, extension of which measures resistance.
K K Index Arm, communicating extension of Spring to Cylinder
W Counterbalance to Index Arm
L Fulcrum of Index Arm, carried by bar b b

REFERENCES.

M M Lever communicating extension of Spring to Index Arm.
N Connecting Link, medium of communication of extension of Spring to Index Arm.
O O Towing beam, holding fore end of Spring.
P Brass Cap, about which b b and M M hinge.
Q Q Bar uniting head of Towing Beam and Cap P to frame carrying Cylinder.
R R Bell Crank for extending Spring by known weights hung on at c, thereby testing Scale.
d d Connection of Bell Crank with Spring.
e Weight giving initial extension to Spring, forming zero of Scale.
S Pen registering extension of Spring.
U U Revolving Cylinder receiving paper on which is registered motion of Pen &c.
T T Frame carrying Cylinder &c, capable of vertical adjustment.
V Time Pen worked by Clock work.
g g Gear for transferring motion of Carriage to Cylinder U U

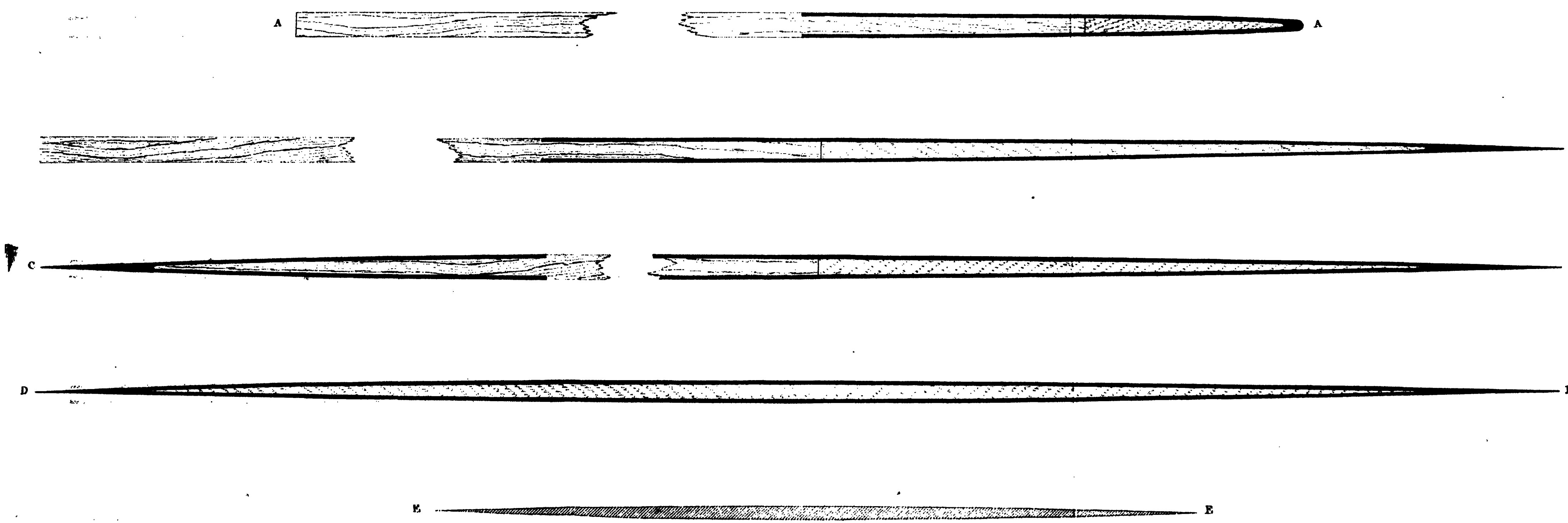


Engraved by Chas. Ingram

Experiments on Surface Friction.

Longitudinal Sections of Planes used in the Experiments.

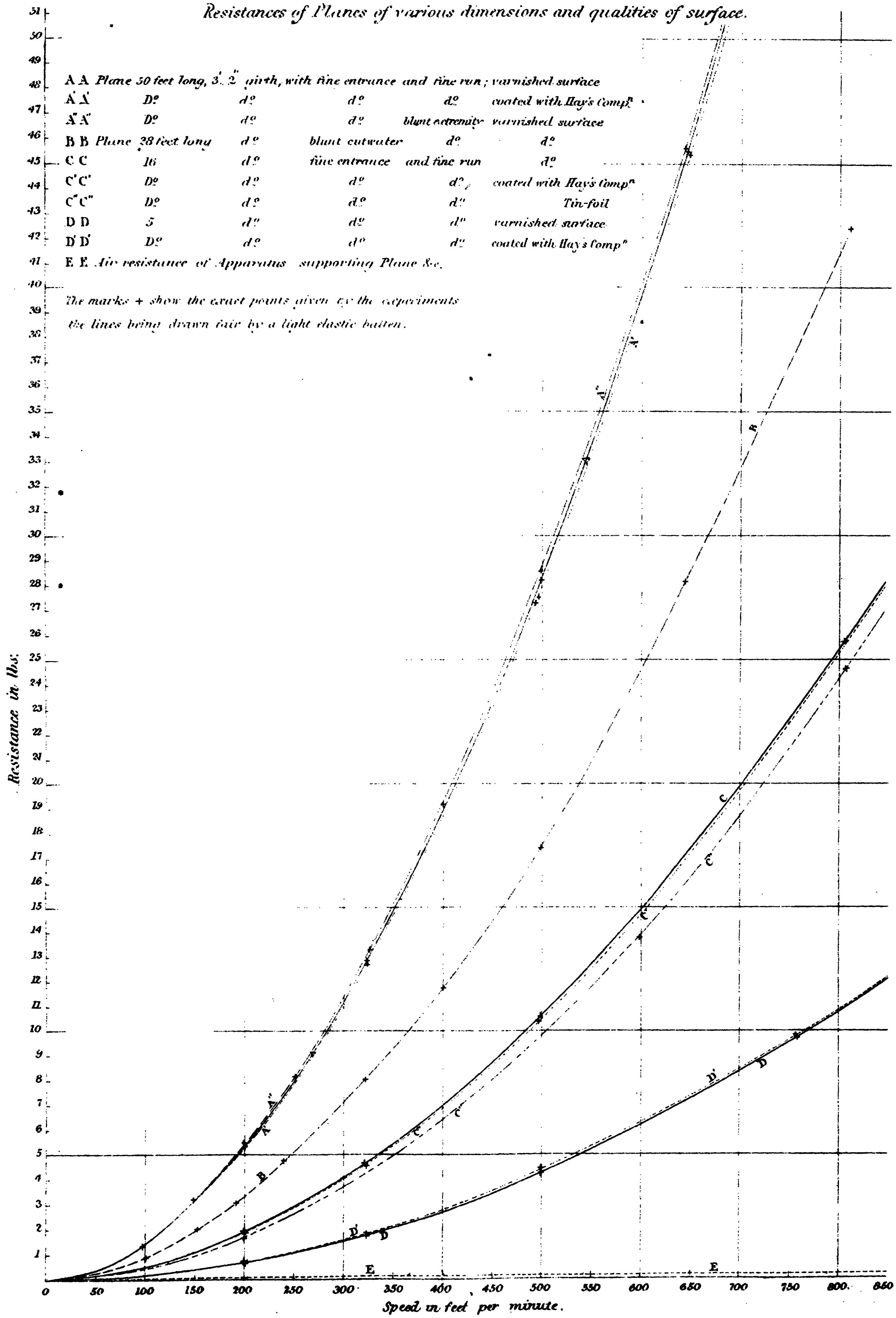
Full size



Engraved by Chas. Tugnon.

Experiments on Surface Friction:

Resistances of Planes of various dimensions and qualities of surface.



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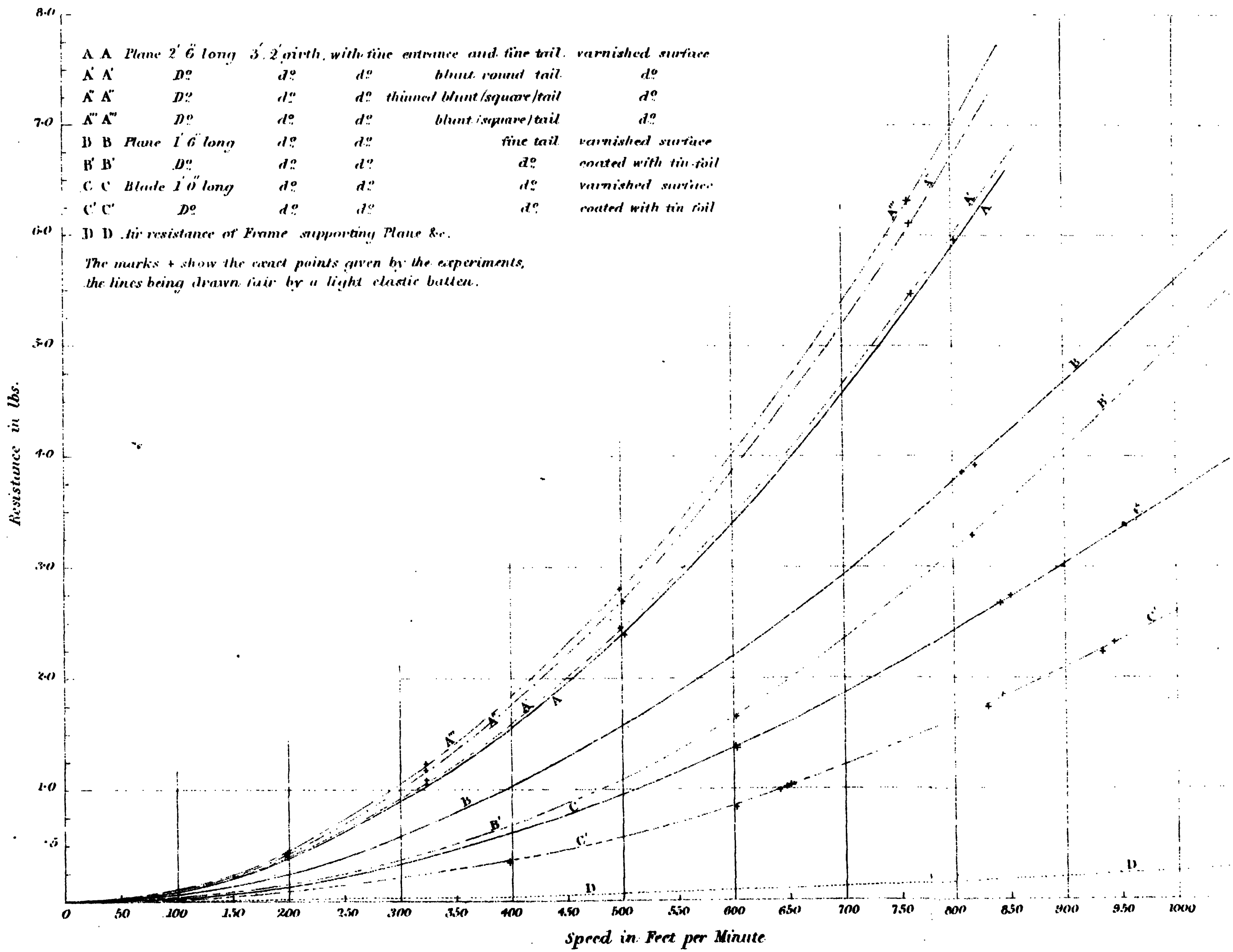
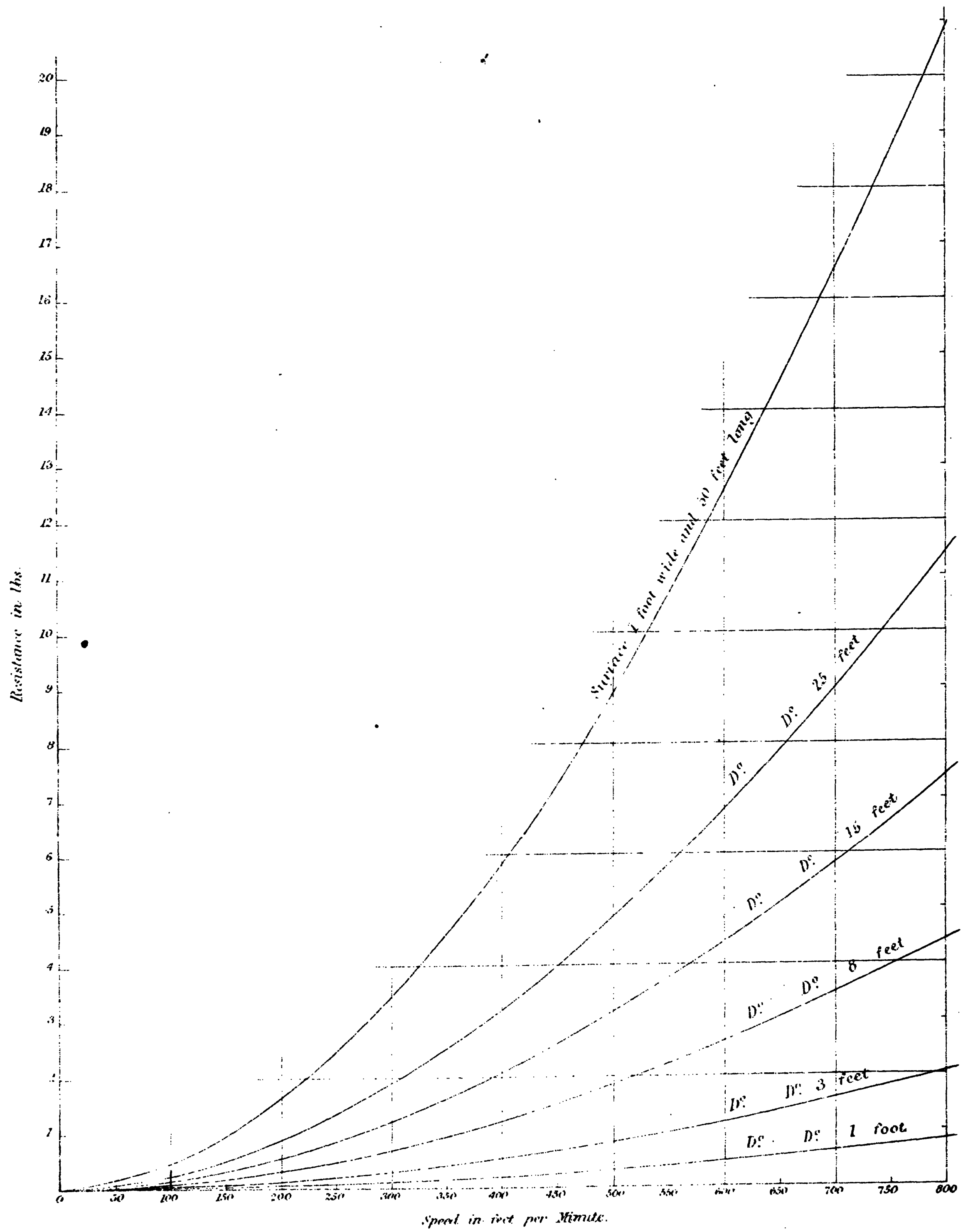


Engraved by Chas. Ingram.

Experiments on Surface Friction.

Total Resistances of surfaces of various lengths, reduced to one foot of area per foot run.

Surfaces coated with shell-lac varnish, Peacocks or Hays composition, or tallow.



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Experiments on Surface Friction

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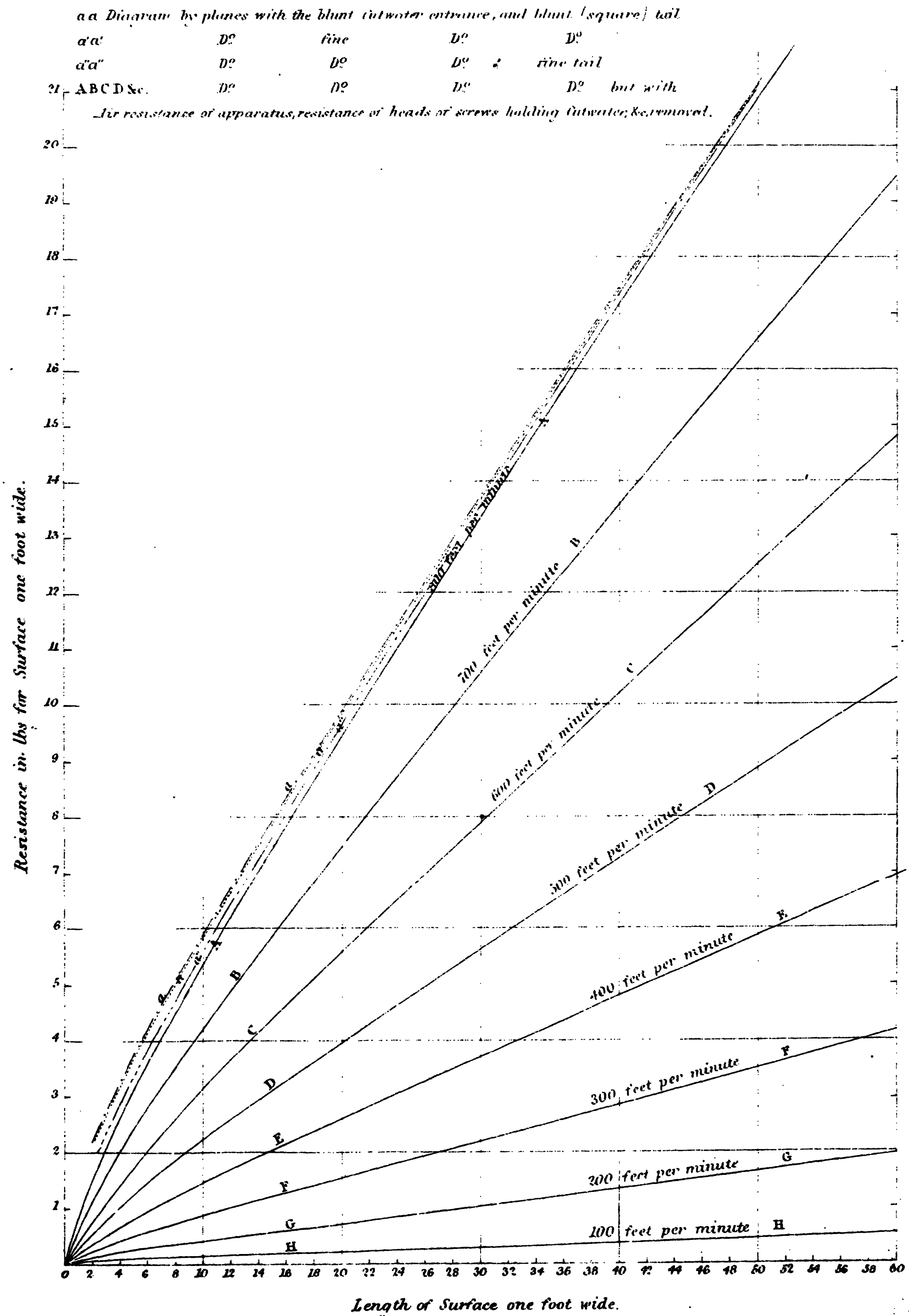


Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position.
1872. July 22	h m 8 55 p.m.	Bridgewater ...	= Sirius	Orange-red ...	1·25 second ...	From 2° above Altair to about 5° N. of east, 12° above the horizon.
		[Seen also at Chelmsford.]	Large	Bluish	6 secs.; slow speed.	About halfway up in the sky.
22	About 9 p.m.	Cookham, Berks. [Seen also at Sittingbourne, Kent.]	Large	Intense white, afterwards dull red.	....	Passed within 20° of the zenith. [Seen also in the east at Pontypool; a comet-like star with a following star.]
22	About 9 p.m.	Street, Somersetshire.	Large and very bright.	Bright bluish green.	4 seconds, or perhaps a little less.	From 45° above the E.S.E. horizon to 25° above the E.N.E. horizon.

Experiments on the Surface-friction experienced by a Plane moving through water. By W. Froude, F.R.S.

[A communication ordered by the General Committee to be printed *in extenso.*]

(Plates II.-VII.)

The object of these experiments is to discover the conditions of the resistance to passage through the water caused to models or ships by the friction of the water against the sides.

This has been investigated by towing, with the dynamometric apparatus, planes formed of thin boards; these being bodies of such a form as to possess the least possible displacement, and present to the line of motion the least possible sectional area, compared to the amount of wetted skin, and at the same time, owing to their flotation, capable of being made stable and self-supporting in the water, though entirely submerged.

The dynamometric arrangement is as follows:—

The water space is a parallel-sided tank 278 feet long, 36 broad at the top, and 10 feet deep; but for the surface-friction experiments it was necessary to lower the water-level about 15 inches.

The tank is roofed from end to end, and a light railway, carried by the framing of the roof, traverses its entire length at about 20 inches above the normal water-level, there being a clear space between the rails, the gauge of which is independent of sleepers or transomes.

A stout framed truck, suspended from the axles of two pairs of wheels, runs on the railway, and is moved by an endless wire rope, coiled in a spiral groove on an accurately turned barrel, which is driven by a small double-cylinder engine, having a heavy and highly speeded fly-wheel, and a chro-

Length of Path.	Direction.	Appearance; Remarks, &c.	Observer.
20°	Slope about 35° .... 	Observed the disappearance by turning round from west, seeing probably only the "spark" at the end; beginning seen by others in the town. β Pegasi only just visible in the strong twilight.	J. E. Clark.
....	From E. to W.—H. J. Impey. (J. E. C.)		
About 40° while in sight.	From a little W. of S. to a little E. of N.	Left no streak visible in the bright twilight. Disappeared without bursting, dying out to a red cinder, which went on some distance on the same course.	R. W. Rogers.
About 50° ...		Left some sparks behind it at last, and some on its track, but no persistent streak. Disappeared like the ball of a rocket, one spark proceeding onwards some way.	W. S. Clark, H. P. Bright Clark, and others.

nometric governor of very exact action, and of such arrangements that any required steady speed between 100 and 1000 feet per minute can be assigned by it to the truck.

The truck carries the dynamometric apparatus. A skeleton diagram in Plate II. shows this in full detail, with the special fittings by which it was adapted to the surface-friction experiments; and as the diagram is fully referenced, the apparatus will be better understood by inspection than by a verbal description here. Its general character is, however, as follows:—

The plane of which the resistance is to be tested is driven through the water by a suitable frictionless attachment, so arranged that the horizontal force driving it is wholly delivered by a spiral spring, like that of a spring balance, the fixed end of which is held by a strong bracket descending from the frame of the truck. The extensions of this spring under the various forces applied form in each case a measure of the force. The extensions, brought to an enlarged scale by a lengthened index-arm, are self-recorded by a pen which follows the motions of the arm, and traces a line on a sheet of paper carried by a cylinder which receives its motion by a band from a pulley on the hinder axle of the truck, so that the circumferential travel of the paper represents on a small scale the forward motion of the truck. A second pen, actuated by clockwork, marked time on the cylinder as it revolved; so that in each experiment two lines were marked on the paper, one showing the resistance experienced at each point in the run, the other showing the speed at which each portion of the run was performed.

The planes were about $\frac{3}{16}$ inch thick, of various lengths, and as finished were uniformly 19 inches broad, and when under experiment were placed on edge in the water, the upper edge being about $1\frac{1}{2}$ inch below the surface.

The lower edge consisted of a quasi keel of lead of the same thickness as the plane, and made heavy enough to nearly neutralize the flotation of the light wood of which the planes were made. But though thus made stable, and approximately neutralized as to flotation, the plane under experiment required control to keep it resolutely vertical, and the line of its length correctly horizontal, while, nevertheless, it required perfect liberty in the line of motion, in order that the whole towing-strain might be accurately delivered to the dynamometer.

For this purpose a light but stiffened wooden bar (Plate II. c c) was hung longitudinally beneath the dynamometer truck, just clear of the surface of the water. To this the planes were rigidly attached. This bar was carried at each end by a light swing or rocking-frame (E E and E E), thus forming a parallel motion perfectly free longitudinally, and perfectly unyielding transversely. It was of course necessary to extend one of the swings above the point of suspension to carry a weight adjusted so as to counterbalance the weight of the bar, together with any sinking or floating force that the plane might exert; otherwise the frame would not have been in equilibrium in the line of motion except in one position, and in any other position would have exerted a positive or negative force on the dynamometer.

The rigid connexion between the planes (which were of course under water) and the swinging bar or parallel motion (which was above water) consisted of a kind of sheath or cutwater (D D), which received the forward edge of the plane, and had a long upper end, extending out of the water, and fastened to an upright on the swinging bar with three strong pins or bolts. The plane was rebated to receive the sides of the sheath, so that the outside surface at the juncture was flush as far as possible.

The investigation of surface-friction may be separated into three primary divisions:—(1) the law of the variation of resistance with the velocity; (2) the differences in resistance due to differences in the quality of surface; (3) the differences in the resistance per unit of surface due to differences in the length of surface.

The necessity of investigating the latter of these conditions may not be at once apparent, it having been generally held that surface-friction varies directly with the area of surface, and will be the same for a given area, whether the surface be long and narrow or short and broad. It has always seemed to me to be impossible that this should be the case, because the portion of surface that goes first in the line of motion, in experiencing resistance from the water, must in turn communicate to the water motion in the direction in which it is itself travelling; and consequently the portion of surface which succeeds the first will be rubbing, not against stationary water, but against water partially moving in its own direction, and cannot therefore experience as much resistance from it. If this reasoning holds good, it is certain that doubling, for instance, the length of a surface, though it doubles the area, would not double the resistance, for the resistance of the second half would not be as great as that of the first.

In order to reduce the results obtained to the most serviceable form for determining the three separate conditions of resistance enumerated above, it was convenient to represent them graphically, by diagram, in two methods; in both methods the ordinates represent resistance, while the abscissæ represent in the one case velocities, and in the other lengths of surface. Plates VI. and VII. are instances of the two kinds. In the former, if the friction proved to vary as the square of the velocity, the diagrams would be ordinary parabolæ originating at the zero-point of resistance and velocity; in the latter, if the

friction per unit of surface were uniform, as is commonly supposed, throughout the length of the surface, and consequently the total resistance of a plane of given width varied simply as the length, the diagrams would be straight lines, originating at the zero-point of both horizontal and vertical scale. If, again, these lines were straight, but apparently originated at a point above the zero, this would indicate that there was a constant element of resistance throughout (such as head-resistance might be), in addition to the element varying as the length. If, however, the lines were concave towards the base, this would indicate that the friction per unit of surface decreased with increasing length of surface.

Since each plane, when once mounted, was, for convenience, tried throughout the intended series of velocities, the results primarily shaped themselves in the first-mentioned form. Some transcripts of the results as originally so plotted are shown on Plate IV., the lines on which represent the actual resistances for any velocity of certain planes under certain differences of condition as specified in the margin of the sheet. The cross marks upon the lines show the actual spots decided by the individual experiments made, and from which the curves drawn were deduced. It may be remarked that, with the exceptions which will be subsequently noticed (the lines marked B′ B′, C′ C′), there is scarcely any difference between any of the lines in respect to the law of variation of resistance in terms of velocity, the resistance varying throughout nearly as the power 1·8 of the velocity.

From the great multiplicity of the experiments tried, it would have been confusing to show even a tolerable large proportion of the original reductions. Those given are selected, partly as exhibiting the results of certain slightly varied conditions which will be presently referred to, and partly as fairly averaged specimens which instructively attest the accuracy of the experiments. This is shown, not only by the fairness of the curves passing strictly through all the spots, but also by the consistency of the contiguous lines.

The results which had been thus reduced to diagram according to the first of the two methods supplied the data for constructing a general diagram according to the second method, as shown in Plate VII. The black lines on this figure express the finally analyzed and complete results, for one quality of surface only, up to a length of 50 feet, that being the greatest length that the apparatus can command. It appeared desirable to ascertain the effect of length of surface (at any rate provisionally) before proceeding to try various qualities of surface; and the process by which these results, as given in the diagram, were finally arrived at requires some explanation.

I commenced by a series of experiments on planes of various lengths, from one foot to fifty feet, having all a similar surface.

The results of this first series of experiments, when analyzed, gave lines similar to the dotted line (a a) on Plate VII. This, it will be seen, is concave towards the base, thus indicating that the friction per unit of surface does actually diminish as the length of surface increases. At the same time its form, as it approached the zero of speed, seemed to show, either that this effect was very much more marked in the first two feet of surface, or that there was considerable body-resistance involved. Moreover, the line obtained, if drawn strictly through all the spots determined by experiment, did not give a fair curve.

This might have been thought to be owing to inaccuracy in the apparatus, were it not that experiments, when repeated, always gave identical results, and that, as has been already mentioned, the results for each individual plane were perfectly harmonious, thus indicating that the discrepancy in question

arose from small differences between the individual planes, probably differences in the thickness or nature of edge at their ends, diminishing or increasing the body-resistance.

The initial edge of the planes tried was formed by the sheath or cutwater before mentioned, which held the plane in its place; and this was tapered in horizontal section, from the thickness of the plane to about $\frac{1}{10}$ inch, the extreme edge being rounded, as shown full size in Plate III. (marked A A). At the tail edge there was no sheath, and the board was simply cut off square, as shown in the same figure. Clearly, if there was any great body-resistance due to these blunt ends, as the line $a\ a$ on Plate VII. seemed to imply, then the slight differences in thickness which existed between the different planes might be sufficient to account for the discrepancies between their results. Accordingly experiments were tried with certain of the planes, of various lengths, already tried, but substituting a cutwater having a very thin edge, tapering to the thickness of the plane in 6 inches, as shown in horizontal section on Plate III. (marked B). This alteration produced a slight diminution in the amount of the resistance of all the planes, but rather a greater reduction in the short planes than in the long ones. The difference, though almost too small to show, is indicated by the line $a'\ a'$, Plate VII. Experiments were then tried with the tail edges of the planes, tapered in the same manner as the initial edge (C, Plate III). This was tried with the result (indicated by the plain line A, Plate VII.) of a very much larger reduction in the resistance; and this reduction was likewise relatively greater in the shorter lengths.

In order still more correctly to obtain a value by which the results of all the planes already tried might be corrected for the varying thicknesses of their after edges, an experiment was tried with one of the thickest planes (2 feet 6 inches long) by reducing the thickness of its square-edged tail to that of the thinnest of the planes (a reduction of perhaps $\frac{1}{16}$ inch). The results of this are shown on Plate V., where the resistance of the plane with the thick after edge is shown by the line marked A‴, and the resistance of the same plane with the tail thinned by the line marked A″, and that with the tail tapered to a perfectly sharp edge by the line A.

It is worth notice on this point that the difference between the reduction of resistance found throughout these experiments on sharpening the tail edge, and that found on sharpening the initial edge, seems to be entirely owing to the difference between the original forms of the blunt cutwater and the blunt tail (the former being partly tapered and rounded, while the latter was cut quite square). This was proved by trying the above-mentioned 2-feet 6-inch plane, with its after edge sharpened like the original blunt cutwater. These results are shown on Plate V. by the dotted lines A′ A′, A A, from which it may be seen that the difference between the rounded edge and the perfectly sharp edge is comparatively small.

The application of the corrections obtained as I have here described to the results of the experiments previously made gave diagrams of resistance in terms of length similar to the line marked $a''\ a''$, Plate VII., the discrepancies between the planes disappearing when thus corrected. But these experiments did not include any made with shorter planes than 1 foot 6 inches, that being the shortest length that could be constructed with the existing cutwater; and in order to make it complete, it was most desirable to extend the lines as far as possible towards the zero-point of length and of resistance, by trying very short and thin planes, so as to test the nature of the curve close to the origin, and discover whether any body-resistance remained owing to the thickness of the plane hitherto tried.

It was also necessary to eliminate certain other constant resistances known to exist, namely, that due to the air-resistance on the swinging bar, that due to the excess of surface of the cutwater, owing to its projecting up through the water above the upper edge of the planes, and that due to the projections and irregularities on its surface, caused by the fastenings of the planes. Of these, the air-resistance was obtained by direct experiment; that due to excess of surface was calculable on the data already possessed; and the resistance due to the projections &c. was determined by trying the 1-foot 6-inch plane, with its surface smoothed up with paraffine and varnished as before. The deduction of these constants brought down the line to the plain lines shown on Plate VII.*

But the first-mentioned object, that of deciding the friction of very short lengths, I have so far been unable to treat quite satisfactorily, owing to the difficulty of guiding very thin blades. I have, however, obtained good results with a 12-inch blade and a 6-inch blade (see Plate III. D, E) sharp on both edges, both about similar in longitudinal section to the 1-foot 6-inch plane; and the experiments with these gave spots through which the curves on Plate VII. were drawn for the first 1-foot 6-inch length of surface.

And though, in the absence of any successful experiment with blades of different thicknesses but the same length, we can scarcely regard as disproved the existence of possible body-resistance due to the thickness, slight as it was, of the planes tried, it is obvious that it would be difficult to deduct further from the diagram of resistance any considerable constant representing this, without making the friction per unit of surface decrease with increasing length less in the first 6 inches than it would be naturally expected to do; in other words, without making the curvature of the lines on Plate VII. less sharp at their origin than would be expected, seeing that in the rest of the diagram the curvature becomes rapidly flatter as the lengths of plane become greater; but indeed the thinness of the planes and the smallness of the reduction of resistance which followed the substitution of knife-like for rounded edges render it almost impossible to credit body-resistance with any appreciable item in the account. It is also most desirable to extend these experiments to greater lengths of surface than I have been able to try with this apparatus. But it would indeed be almost impossible to do so in the experiment tank; and I shall endeavour to organize some arrangement by which greater lengths may be successfully tried in open water.

I have thus far confined myself, in the description of the result, to the question of the effect of lengths of surface upon resistance. I have now to deal with the question of quality of surface.

The different surfaces tested may be enumerated as follows:—

Shellac varnish.
Hay's composition.
Peacock's composition.
Tallow.
Glue.
A smooth metal surface obtained by a coating of tinfoil.

The comparison between the first three named was made with planes 5 feet, 16 feet, and 50 feet long, which were each coated first with Hay's and subsequently with Peacock's composition, all the planes having been previously

* It should be noticed, however, that the scale of resistance shown on Plate VII. gives, not the actual resistances due to the planes tried, but the reduced resistance due to a surface *one foot* wide and of the lengths shown.

tried as coated with shellac varnish. The comparison between the shellac and the Hay's composition is exhibited in Plate IV., in which the plain lines marked A, C, and D represent the result with the shellac, and the dotted lines marked A′, C′, and D′ that with the Hay's composition. These two results I consider practically identical, since such small difference as is observable might possibly arise from some other difference in the condition of the plane; and it is observable that with the 5-foot plane D, D′ the scarcely perceptible difference is opposite in character to that shown by A′, A and B′, B.

The results with Peacock's composition are not shown in Plate V., being practically identical with the other two.

The tallow surface was tried on the 16-foot plane only, and gave no difference, the diagrams falling between that of the shellac and that of Hay's composition.

The glued surface was tried as a specimen of a slimy, fish-like surface, which should partly wash off in the water. The glue was allowed to harden before being put in the water; and to test its change of condition consequent on immersion, three experiments were tried successively at the same velocity. The resistance was thus found to be throughout on the increase, the first experiment being about two per cent., and the third about four per cent. greater than that of the shellac surface, apparently implying that the resistance was increased by the softening of the surface.

The tinfoil surface is the only surface I have yet tried which I have found to have a resistance greatly different from that of varnish; and here it is remarkable that the difference tends to be much less in the greater lengths of surface. It is consequently most unfortunate that, owing to the delay I experienced in getting the tinfoil for the purpose, it became impossible to try it on a greater length than the 16-foot plane in time for this Report. The comparison of the tinfoil surface with that of the varnish was made on lengths of 16 feet, 1 foot 6 inches, and 1 foot. The results with the 16-foot plane tinfoiled are shown by the dotted line marked C″ in Plate IV.; those with the 1-foot and 1-foot-6-inch tinfoiled are shown in Plate V. by the dotted lines marked B′ and C″ respectively. For comparison with these, Plate V. also shows the results of the same lengths varnished, by the plain lines marked B and C respectively.

It will be seen by these diagrams that not only is the difference of resistance between tinfoil and varnish proportionately less in greater lengths of surface, but is also proportionately less at greater speeds; consequently the law of the increase of resistance in terms of velocity is obviously different in the case of the tinfoil from what it is in the case of the varnish and the other surfaces which were tried.

Report on the Antagonism between the Action of Active Substances. By THOMAS R. FRASER, *M.D., Secretary to the Committee, consisting of* Sir R. CHRISTISON, *Bart.,* Dr. LAYCOCK, *and* Dr. FRASER.

THE subject of the antagonism between the actions of active substances has engaged considerable attention from an early period of medical history. Many examples of its occurrence have been brought forward, which may be conveniently classified into those that treat of the antagonism of *lethal actions,* and those that treat of the antagonism of *non-lethal actions.*

In the latter class there are several well-authenticated examples, among which may be instanced the antagonism between the actions on the iris and minute blood-vessels of opium or morphia on the one hand, and belladonna, hyoscyamus, and stramonium on the other; between the actions on the capillary circulation of morphia and quinia; between the actions on the vagi nerves of physostigma and atropia, hydrocyanic acid and atropia, and muscaria and atropia; and between the actions on the iris and on visual accommodation of physostigma and atropia.

In the *former* class the examples are likewise numerous; but a careful examination of the evidence in their support cannot fail to lead to the conclusion that, with very few exceptions, it is of an unsatisfactory nature. In the majority of cases where an active substance has acquired the reputation of counteracting the fatal effect of some other substance or substances, this reputation has mainly been founded on the results of clinical experience. In such experience there are difficulties in discovering not only what dose of poison has been introduced into the system, but even when this dose has been ascertained it is generally impossible to feel assured that it is a sufficient one to produce death; and, further, the effects of the substance introduced as a physiological antidote can rarely be accurately observed. The exigencies of treatment demand that every likely method of alleviating the symptoms should be applied; and among these it is difficult, if not impossible, to discover accurately the effects of any single antidote. It is not therefore to be wondered at that the accumulated clinical observations of more than two centuries should have failed in *proving* that opium is able to prevent the fatal effect of belladonna, and that this evidence has equally failed in establishing the existence of any one of the examples of lethal antagonism to which attention has more recently been drawn.

A method whereby the existence of a lethal antagonism can satisfactorily be tested is by experiment on the lower animals. In such experiments the most important of the causes of fallacy that have been alluded to can readily be avoided. It is a simple matter to determine, in any given species of animal, the minimum dose of an active substance that can produce death, and then to test the antidotal influence of its supposed antagonist when a lethal dose of the poison has been administered. The most convincing proof may be thus obtained of an antidotal influence; and trusting to this proof, the practitioner may with confidence employ the antidote in cases of poisoning in man. It is unnecessary to show that the fallacies asserted to exist in such experiments have been greatly exaggerated, or that the supposed differences between the results in man and in the lower animals do not possess the importance that has been claimed for them, as fortunately nothing remains to be done in this direction since the convincing arguments of Claude Bernard have been advanced and generally accepted.

In this Report it is proposed to bring before the Association the results of an investigation in which the influence of atropia upon the lethal action of physostigma was examined, by experiments on the lower animals. The nature of this influence may be shown by a brief account of two of the experiments that were made.

A rabbit received by subcutaneous injection a dose of extract of physostigma considerably greater than the minimum lethal; and one minute and a half afterwards it received, also by subcutaneous injection, half a grain of sulphate of atropia. In seven minutes after the injection of atropia the pupils measured $\frac{18}{50} \times \frac{18}{50}$ of an inch, the size immediately before the ex-

periment having been $\frac{19}{50} \times \frac{9}{50}$ of an inch; the rate of the heart's contractions was considerably accelerated; fibrillary twitches were occurring, and a little restlessness was present. Soon afterwards the pupils became still further dilated, and the animal had some difficulty in moving about. In fifty-two minutes the pupils measured $\frac{15}{50} \times \frac{14}{50}$ of an inch, and the difficulty in moving about had become greater. In one hour and ten minutes, however, evidences of recovery were manifested; the animal went about with but little difficulty, and frequently a perfectly normal sitting posture was assumed. Indeed the only symptom of an abnormal character that was now apparent consisted of frequently occurring and well-marked fibrillary twitches. From this time the condition of the animal steadily improved, until perfect recovery occurred. As the minimum lethal dose of this preparation of physostigma, for any given weight of rabbit, had been determined by a preliminary series of experiments, it was known that the dose given in this experiment was rather more than twice as large as the minimum lethal. Yet the fatal effect of this large dose was prevented in a remarkable manner by the dose of atropia given in conjunction with it. To add to the proof that was thereby obtained, of an antagonism between these two substances, there was administered to this rabbit, nine days afterwards, a dose of extract of physostigma, only half as large as that from which it had thus recovered. Symptoms of poisoning very quickly appeared, and death occurred in about fourteen minutes.

In the second experiment, a dog, weighing ten pounds and three ounces, received by subcutaneous injection three fifths of a grain of sulphate of physostigmia, dissolved in a few drops of distilled water. Before the injection the rate per ten so onds of the cardiac impulses was 32, and that of the respirations 4, and the size of the pupils was $\frac{12}{50} \times \frac{12}{50}$ of an inch. In four minutes after the administration of physostigma slight tremors occurred, and fibrillary twitches were present. In five minutes a solution containing three tenths of a grain of sulphate of atropia was injected under the skin. In two minutes thereafter the tremors had become more prominent and strong, the limbs were unable properly to support the body, saliva escaped from the mouth, and the eyeballs were unnaturally moist. In five minutes the pupils were greatly dilated; but now the secretions of the salivary and lachrymal glands were diminished. In seven minutes the dog lay quietly on the abdomen and chest, but in thirteen minutes it fell over on the side. This general condition remained until forty-eight minutes, when the symptoms improved; and after some efforts the dog rose, and then lay down in a normal crouching posture. Soon afterwards it again got up and walked about the room with only a little unsteadiness. In one hour and fifty-five minutes the animal seemed to be perfectly well.

Nineteen days after the performance of this experiment, the same dog received by subcutaneous injection a dose of sulphate of physostigmia only one half as large as that from which it had recovered when atropia was also given. and the result was that death was produced in twenty-two minutes.

It is manifest that in these two experiments atropia acted as a physiological counteragent to the toxic action of physostigma. In other 195 experiments the fatal effect of undoubtedly lethal doses of physostigma was likewise prevented by atropia. This investigation has therefore proved that atropia is a counteragent to the lethal action of physostigma.

As both of these substances possess a number of separate actions, it was not unreasonable to anticipate that several of them are not mutually antagonistic, and therefore that combinations of certain doses of the two substances may

be administered whereby the non-antagonized actions will be produced in sufficient degrees of energy to be able to cause death. It was probable, therefore, that successful antagonism would not be exerted throughout an unlimited range of doses, but only within a definite range.

In order to define the limits of the counteracting influence of atropia upon the lethal action of physostigma, three series of experiments were made.

It was found necessary to make all the experiments of these three series on rabbits, as it was impossible to obtain a sufficient number of any other suitable animal. The rabbits used were generally about three pounds in weight; but when they were lighter or heavier than three pounds a correction was made, so that each dose represented three pounds weight of animal.

In the first and second series a constant interval of time was maintained between the administration of the two substances; but in the first atropia was administered five minutes *before* physostigma, while in the second atropia was administered five minutes *after* physostigma. In both of these series experiments were made, in the first place, with the minimum lethal dose of physostigma, and in combination with it various doses of atropia were given, ranging from one that was too small to prevent death, through a number that were able to do so, until a dose was found whose administration resulted in death. Similar experiments were made with a dose of physostigma once and a half as large as the minimum lethal; then with one twice as large as the minimum lethal, and so on, at the same rate of progression, until a dose was reached that was too large to be successfully counteracted by any dose of atropia.

The results obtained by the *first* of these two series of experiments were, that with the minimum lethal dose of physostigma 0·005 gr. of sulphate of atropia is too small a dose to prevent death, but that 0·015 gr. is sufficient to do so; and that with any dose ranging from 0·015 gr. to 5·2 grs., the fatal effect of this dose of physostigma may be prevented; while if the dose of sulphate of atropia be 5·3 grs. or more, the region of successful antagonism is left, and death occurs. With *once and a half* the minimum lethal dose of physostigma, successful antagonism was produced by doses of sulphate of atropia ranging from 0·02 to 4·1 grs.; with *twice* the minimum lethal dose of physostigma, with doses of sulphate of atropia ranging from 0·021 to 3·2 grs.; with *two and a half* times the minimum lethal dose of physostigma, with doses of sulphate of atropia ranging from 0·025 to 2·2 grs.; with *thrice* the minimum lethal dose of physostigma, with doses of sulphate of atropia ranging from 0·06 to 1·2 gr.; and with *three and a half* times the minimum lethal dose of physostigma, with doses of sulphate of atropia ranging from 0·1 to 0·2 gr. Successful antagonism could not be obtained above this dose, and accordingly three and a half times the minimum lethal dose of physostigma is the largest quantity whose lethal action can be prevented by atropia administered five minutes previously.

The results obtained by the *second* series of experiments (in which atropia was administered five minutes *after* physostigma) were essentially the same as those obtained by the first series, excepting that the region of successful antagonism was found to be a more limited one. In both series the general result was obtained, that the range of doses of atropia capable of preventing the lethal action of physostigma diminishes according as the dose of physostigma is increased.

In the *third* series of experiments, a constant dose of physostigma (once and a half the minimum lethal) was given along with various doses of atropia; and with each of the doses of atropia several experiments were

made, which differed from each other by a difference in the interval of time between the administration of the two substances. On this plan two sets of experiments were made, in one of which atropia was given *before* physostigma, and in the other *after* it; and subsequently these two sets of experiments were connected together by a third, in which atropia, in various doses, was given *simultaneously* with the same dose of physostigma as was given in the two other sets of experiments. The general result of this series of experiments is that successful antagonism occurs with a greater range of doses of atropia, and a greater range of intervals of time between the two administrations, when atropia is given before physostigma than when it is given after it.

An eminent authority in pharmacology has recently published the statement that the only method whereby the injurious action of a poison, absorbed into the blood, can be made to terminate is by the employment of such means as will cause or hasten the elimination of the poison. This statement, fortunately, does not accurately describe our remedial resources. The existence of so undoubted an example of physiological antagonism as that between atropia and physostigma shows that the toxic influence of a morbific agent may be directly opposed by a physiological antidote, and that recovery may be produced by influencing the abnormal conditions themselves, in such a manner as to cause their return to a normal state.

Fifth Report of the Committee, consisting of Sir W. Thomson, *F.R.S.*, Professor Everett, Sir Charles Lyell, *Bart.*, *F.R.S.*, Professor J. Clerk Maxwell, *F.R.S.*, Professor Phillips, *F.R.S.*, G. J. Symons, *F.M.S.*, Professor Ramsay, *F.R.S.*, Professor Geikie, *F.R.S.*, James Glaisher, *F.R.S.*, Rev. Dr. Graham, G. Maw, *F.G.S.*, W. Pengelly, *F.R.S.*, S. J. Mackie, *F.G.S.*, Professor Hull, *F.R.S.*, *and* Professor Ansted, *F.R.S.*, *appointed for the purpose of investigating the Rate of Increase of Underground Temperature downwards in various localities of Dry Land and under Water. By* Professor Everett, *D.C.L.*, *Secretary.*

In December last intelligence was received from Prof. Sismonda that the administration of the railway owning the Alpine tunnel had given permission to Father Secchi to carry on a series of observations in the tunnel concerning terrestrial magnetism, and that this distinguished observer was willing at the same time to conduct observations of temperature in accordance with the plans of your Committee. Two maximum and two minimum thermometers were accordingly placed in Father Secchi's hands; but it appears that the arrangements for commencing the magnetic observations are not yet completed, and that accordingly no observations of temperature have as yet been taken.

Prof. Lubimoff, of Moscow, on receiving a copy of last year's Report, wrote to the Secretary, correcting a mistake in the description of the thermometer used in taking observations in the Moscow well. The thermometer was enclosed in an hermetically sealed case containing air, and was therefore completely protected against any possible effect of pressure. Prof. Lubimoff at the same time asked to be furnished with a thermometer

of the new pattern described in the Report (the upright Negretti pattern), and one of these instruments was accordingly sent.

Dr. Wild, of the Central Observatory, St. Petersburg, wrote in January, requesting that two thermometers for observations in bores might be ordered in his name. At this time the Secretary was in correspondence with Sir Wm. Thomson, who entertained doubts as to the successful working of the new thermometer, and expressed a preference for the Phillips pattern (which has been described in preceding Reports) and the Casella-Miller pattern (a modified Six), which has been extensively used for deep-sea temperatures. Thermometers of these two patterns were accordingly ordered and despatched to Dr. Wild.

A letter was received from Prof. Henry, of the Smithsonian Institution, Washington, in April, stating that the Chief Engineer of the Hoosac Tunnel had promised to have observations of temperature taken in the tunnel, if thermometers were sent. Its total length will be $4\frac{3}{4}$ miles, about two thirds of which has been penetrated, by working from both ends and from a central shaft 1028 feet deep. The mountain has two ridges, under which the tunnel passes, and their heights above it are respectively 1720 and 1420 feet. Four thermometers have been sent, viz. two large minimum Rutherfords, for observations in the tunnel, and two upright Negrettis, for observations in the shaft.

The Council of the School of Mines at Ballarat, Australia, have, in compliance with a request addressed to one of their number by our observer, Mr. David Burns, C.E., consented to take charge of some thermometers, and to furnish observations from the bores and shafts in that important gold-mining district. Most of the principal mining managers are connected with the school. Four thermometers have accordingly been sent, viz. two upright Negrettis for observations in bores, and two simple mercurial thermometers, of large size, for observations during the sinking of shafts.

Some exceedingly deep Artesian borings have been undertaken in France in recent years; and the President of the Geological Society, Mr. Prestwich (who has allowed his name to be added to your Committee), has furnished your Secretary with introductions which will probably lead to the obtaining of very numerous and valuable observations from these wells.

The largest of them all is one which is now sinking for the municipality of Paris, at La Chapelle, St. Denis, a northern suburb of Paris, and has already obtained a depth considerably exceeding that of the Puits de Grenelle. It is expected that its final depth will be about 2300 feet. Application was made by the Secretary to the eminent firm of well-borers, Messrs. Mauget, Lippmann, and Co., who are sinking the well, and these gentlemen at once, in the most obliging manner, consented to take observations of temperature in it. An upright Negretti thermometer was accordingly furnished; and about the 20th of June your Secretary had the pleasure of receiving from them two complete sets of observations taken on the 14th, 15th, 17th, and 18th of that month with their own hands, at every 100th metre of depth, and also at the bottom of the well, 660 metres deep.

The observations are given in the subjoined Table, in which the third column shows the time that the thermometer was allowed to remain at the depth specified before hauling up and reading. The temperature at which the thermometer was set before letting it down is also given in Messrs. Mauget and Lippmann's report, but is not here inserted.

	First series, June 14, 15.		Second series, June 17, 18.	
Depth, in metres.	Temperature, Fahrenheit.	Time down.	Temperature, Fahrenheit.	Time down.
	°	h m	°	h m
100	58·0	0 35	58·0	3 25
200	61·1	0 30	61·0	2 0
300	65·0	0 30	65·0	2 0
400	69·0	3 10	69·0	11 20
500	72·6	0 30	72·6	2 0
600	75·8	0 30	75·4	2 0
660	83·25	15 45	83·25	2 0

The agreement between the first and second set of observations is remarkably close; and as the time of leaving the thermometer in the water was about half an hour in most of the observations of the first set, and two hours or more in all the observations of the second set, it is obvious that half an hour is a sufficient time to give a correct observation. This conclusion is satisfactory both as regards the reliability of the observations themselves, and also as establishing the fact that this pattern of thermometer is not unreasonably slow in its working. The exactness of the agreement also serves to show that the thermometer can be depended on to the tenth of a degree, and that we may henceforth use it with confidence.

Before proceeding to discuss the observations, it will be convenient to give a few particulars respecting the well, which have been kindly furnished by Messrs. Mauget and Lippmann.

It was commenced by the municipal authorities as a masonry well, by the ordinary method of digging, until it had reached a depth of 34·5 metres. The intention was to carry it in this way to the depth of about 135 metres, the estimated depth of the tertiary strata covering the chalk; but the difficulties and dangers which were encountered, from the want of tenacity in the soil (*la nature essentiellement éboulеuse des terrains*), and latterly from the insufficiency of the pumps, rendered it necessary to abandon this intention; and in May 1865 the task of completing the well by boring was assigned to Messrs. Degousée and Laurent, the predecessors in business of the gentlemen to whom we are indebted for these observations. A small trial bore (0·2 metre in diameter) was commenced, and continued till January 1866, by which time the machinery for the heavier work was ready. In order to support the masonry, which showed signs of giving way, it was tubed through its whole length with a tube 1·8 metre in diameter and 0·02 metre thick, cemented externally. From the bottom of this tube, at the depth of 34·5 metres, a bore 1·7 metre in diameter was carried to the depth of 68·7 metres from the surface of the ground. A second tube 1·58 metre in internal diameter was inserted to the depth of 121·6 metres, and a third tube of internal diameter 1·39 metre was carried down into the chalky marls and the upper portion of the chalk at the depth of 139·15 metres from the surface. From this point downwards, the bore has been driven through the chalk, and tubing has been unnecessary, its diameter at the depth of 662 metres being still 1·35 metre.

The thickness of the tertiary strata is 137 metres, and the elevation of the surface of the ground above sea-level is 48 metres, or 157 feet.

The springs which were met with in the tertiary strata correspond to those found in other parts of the basin in which Paris is situated, and have not sufficient strength to spout above the surface of the ground at this elevation. They were encountered at the depths of 19·2 metres, 34·5 metres, 86 metres, and 97 metres, and the water now stands in equilibrium in the central tube at 16·5 metres below the surface of the ground.

It was not practicable to take observations of temperature during the regular progress of the boring; but an interruption occurred on the 12th of June, and the tool was not at work from this date till after both sets of observations were finished. In reference to this point, Messrs. Mauget and Lippmann say, under date April 29, "To obtain the natural temperature, it will be necessary to select a time when the work has been interrupted for several days; for the boring being executed by the fall of a heavy tool upon the bottom of the well, the percussion developes a considerable amount of heat, as we perceive by the mud (*les boues*) which we extract, and which in coming to the surface is found to have still a temperature of from 48° to 90° C. (118° to 194° F.)." In their letter of June 19, containing the report of the observations, they remark:—

"You will observe that though the water at the bottom of the well is still some degrees above its natural temperature owing to the action of the drill (*trépan*), the latter has not been in operation since the 12th of the month. At a convenient time, we intend to observe the temperature of the mud as it lies at the bottom of the well, immediately after the withdrawal of the drill, when the latter has been working constantly, a temperature which will probably be found to depend upon the hardness of the rock."

The following Table exhibits the successive increments of temperature shown in the second series, which purports to be the more accurate:—

Depth, in metres.	Increase in deg. Fahrenheit.	Metres per deg. Fahrenheit.	Feet per deg. Fahrenheit.
100 to 200	3·00	33·3	109
200 to 300	4·00	25·0	82
300 to 400	4·00	25·0	82
400 to 500	3·60	27·8	91
500 to 600	2·80	35·7	117
600 to 660	7·85	7·6	25

The last two columns of this Table show that the rate of increase is about four times as rapid in the last 60 metres as in the rest of the well, a circumstance which naturally suggests the explanation given by Messrs. Mauget and Lippmann. There are, however, some difficulties in the way of accepting this view. Comparing the two sets of observations, one taken on the second and third day after the withdrawal of the tool, and the other on the fifth and sixth day, we have precisely the same temperature at the bottom of the well on both occasions, although the observations were sufficiently precise to detect a difference of a tenth of a degree where such difference existed. It seems difficult to believe that a temperature $2\frac{1}{2}$ degrees above the normal

temperature could have remained for two days without sensible diminution. In connexion with this question, the apparent cooling to the extent of 0°·4 at the depth of 600 metres between the first and second observation demands attention, and is not very easily explained.

If the observed temperature at 660 metres is to be taken as the normal temperature, the average increase from 100 metres to that depth is at the rate of 1° F. in 22·2 metres, or in 72·8 feet. If the observed temperature at 600 metres in the second series is adopted, the increase from 100 metres to that depth is at the rate of 1° F. in 28·7 metres, or in 94·3 feet.

The observations proposed by Messrs. Mauget and Lippmann in the paragraph above quoted will be eminently calculated to assist in showing the correct interpretation.

Mr. G. A. Lebour, F.G.S., of H.M. Geological Survey, has furnished observations taken in a bore-hole executed at the bottom of South Hetton Colliery, Durham. The observations were taken by Mr. J. B. Atkinson, a student at the Newcastle College of Physical Science, and appear to have been carefully made. Thanks are also due to the viewer of the colliery, Mr. Matthews, for granting the requisite facilities.

The hole is $2\frac{1}{2}$ inches in diameter, and was bored out of the pumping side of the South Hetton shaft, in order that the bore-rods might be the more readily altered. The depth of the shaft is 1066 feet, that of the bore-hole 863 feet from the bottom of the shaft, or 1929 feet from the surface of the ground. The section of the boring (not including the shaft) consists of 123 alternating beds of shale and sandstone*, with occasional thin seams of coal and some fire-clays. The bottom of the boring has reached a very coarse white grit, which is supposed to be the topmost bed of the Millstone-grit series.

The bore was dry at the time of its execution, but has since become filled with water, probably derived from the shaft above it. Streams, in fact, pour down the shaft and play about the hole.

Two thermometers, one of them an unprotected Phillips, and the other a protected Negretti, were supplied by the Secretary to Mr. Lebour, as it was not certainly known at that time whether the bore was dry or wet. Mr. Lebour indeed believed it to be dry, but nevertheless selected the Negretti thermometer, as it was thought that the Phillips could not be read off accurately with the poor light which in the position of this bore-hole was alone available.

The following Table exhibits the results of all the observations which have been taken in the bore, including three which were taken in 1869, while the boring was going on. The boring was stopped, in the case of each of these three observations, only about 20 minutes before the observations were made; and the heat due to friction appears to have produced abnormal elevation of temperature, amounting to about 2° at the depth of 288 feet, to about 6° at the depth of 582 feet, and to considerably more than this at 858 feet. The other observations in the Table are Mr. Atkinson's, taken with the Negretti thermometer.

* A complete list of the strata has been furnished, and will be preserved by the Secretary, with a view to future reference if required.

Depth from bottom of shaft, in feet.	Depth from surface of ground, in feet.	Temperatures observed during boring, April 1869.	Temperatures observed April 1872.
100	1166	° ..	° 66
200	1266	..	$68\frac{3}{4}$
288	1354	72	
300	1366	..	70
400	1466	..	72
500	1566	..	$74\frac{1}{2}$
582	1648	82	
600	1666	..	$76\frac{1}{8}$
644	1710	..	75
670	1736	..	$77\frac{1}{8}$
858	1924	96	

The temperature 75° at the depth of 644 feet, a temperature lower than either of the two between which it stands, was taken on the first day of Mr. Atkinson's observations, and was confirmed by repeated trials at that time. This was the lowest depth that could then be reached, the remainder of the boring being apparently plugged up with "sludge." A spike was subsequently attached to the thermometer case, which enabled it to pierce deeper into the sludge; but the lowest depth which could be reached (670 feet) is still far from the bottom of the bore.

It is intended to take a fresh series of observations at every 50th foot of depth, and especially to reexamine the temperatures at about 650 feet, where the reversal of temperature was observed.

The following are the rates of increase deduced from Mr. Atkinson's observations, omitting the temperature 75° at the depth of 644 feet:—

Depth, in feet.	Increase in degrees, Fahrenheit.	Feet per degree.
100 to 200	$2\frac{3}{4}$	36
200 to 300	$1\frac{1}{4}$	80
300 to 400	2	50
400 to 500	$2\frac{1}{2}$	40
500 to 600	$1\frac{5}{8}$	62
600 to 670	1	70
100 to 670	$11\frac{1}{8}$	51·2

The average increase between the depths of 100 and 670 feet is 1° in 51·2 feet. These depths are reckoned from the top of the bore-hole, which is 1066 feet below the surface of the ground. Mr. Lebour assumes that the temperature at the depth of 60 feet from the surface of the ground is 48°. Accepting this estimate, we have a difference of $29\frac{1}{8}$° in 1676 feet ($1066+670-60=1676$), which is at the rate of 1° in 57·5 feet.

Mr. David Burns, F.G.S., reports that, from changes in the management of the mines and other causes, it has not been possible as yet to carry out the dry observations at Allenheads mentioned in last year's Report.

Only one other shaft has been met with at all suitable for observation.

It is called Brandon Walls shaft, and belongs to the Rookhope Valley Mining Company, to the courtesy of whose agent we are indebted for liberty to take observations. This shaft is some 6 miles east of those reported on last year, and is situated in the very bottom of Rookhope Valley. The mouth is covered over with a wooden shed, the shaft itself is free from all obstruction, and the water in it has not been disturbed for some years. The shaft is 333 feet deep, and is full of water to within 25 feet of the surface of the ground. Observations (by Mr. Burns and Mr. Curry, of Bolkburn) were taken in it on five different days in July of the present year; but though agreeing well with one another from day to day, they are so irregular that they throw little light on the rate of increase of underground temperature. At the depths of 83 and 133 feet from the ground the temperature was $48^{\circ}\cdot5$. In the next 50 feet there was an increase of about 3°, the temperature at 183 feet being about $51^{\circ}\cdot4$, and from this depth to the bottom (an interval of 150 feet) the temperature was nearly constant. The best determination of the temperature at the bottom was $51^{\circ}\cdot7$.

It may be remarked that all observations in shafts thus far have exhibited irregularities of this kind. The water in such large openings seems to have its temperature governed by springs and other extraneous causes, rather than by the temperature of the surrounding soil.

The observations at every 50th foot of depth in the Kentish Town well, as given in previous Reports, are so complete that it has not been thought necessary to continue them. A very delicate thermometer, reading by estimation to the $\frac{1}{100}$ of a degree, has, however, been procured, for taking observations from year to year at one constant depth (1000 feet). It was constructed ten months ago, and being enclosed in a partially exhausted glass tube, will probably not undergo much change of zero. It has been four times tested by comparison with standards, and has been found to have no error amounting to nearly so much as $0^{\circ}\cdot1$. In consequence of Mr. Symons's illness, no observation has yet been taken with it in the well.

A Six's thermometer, which, through the breaking of a rope, had fallen into the mud at the depth of 1090 feet from the surface of the ground, was extracted by Mr. Symons last November, more than a year after its fall. It had sustained no damage, and its indication when hauled up was $69^{\circ}\cdot4$, nearly agreeing with the temperature previously observed at that depth.

In addition to the large number of thermometers above mentioned as having been issued during the past year, one has been furnished for observations which are to be made in the projected boring through the Wealden and underlying strata. With the exception of Mr. Symons's observations at Kentish Town (London, N.), we have as yet no observations of temperature from the southern parts of England.

Preliminary Report of the Committee on Siemens's Electrical-Resistance Pyrometer, consisting of Professor A. W. Williamson, *F.R.S.,* Sir W. Thomson, *D.C.L., F.R.S., and* Professor J. Clerk Maxwell, *LL.D., F.R.S.*

The experiments of the Committee have hitherto been confined to testing the electrical permanence of the coil of wire used in the pyrometer. For this purpose the resistance of the coil has been repeatedly taken at known

temperatures, and also at a red heat, at which latter temperature the resistance was about three and a half times as great as at atmospheric temperatures. After being heated, it was found that the resistance of the pyrometer was slightly greater at a low temperature than it had been at the same temperature previously; but the permanent change which thus took place became smaller and smaller after successive heatings, so that the instrument may be expected to reach a condition in which no further important alteration will be produced in it by exposure to a red heat.

The Committee are, however, informed by Mr. Siemens that he believes that the small amount of variation to which the pyrometer, as hitherto constructed, was thus found to be subject, may be considerably lessened, or altogether prevented, by an easy alteration in the mode of enclosing the coil. Under these circumstances it is considered desirable to postpone further trials until the more perfect form of the instrument can be experimented with; the Committee, therefore, suggest that they should be reappointed, and that the grant of £30, made at the last Meeting, none of which has been expended, should be renewed.

Fourth Report of the Committee on the Treatment and Utilization of Sewage, consisting of Richard B. Grantham, *C.E., F.G.S.* (Chairman), Professor W. H. Corfield, *M.A., M.D.*, *J. Bailey Denton, *C.E., F.G.S.*, Dr. J. H. Gilbert, *F.R.S.*, *John Thornhill Harrison, *C.E.*, W. Hope, *V.C.*, *Lieut.-Col. Leach, *R.E.*, Dr. A. Voelcker, *F.R.S.*, and Professor A. W. Williamson, *F.R.S.*

N.B.—Those members whose names have an asterisk prefixed have not attended any meeting of the Committee during the year.

The Committee, since its reappointment at the last Meeting of the Association at Edinburgh, has pursued the inquiry intrusted to it, and, as heretofore, its investigations have been limited to such matters as have afforded the promise of practical utility. Among the various methods of treatment or utilization of sewage brought to the notice of the Committee, that of treating sewage by Messrs. Weare's process at Stoke Union Workhouse, the precipitation and conversion of the deposited matters into cement at Ealing, and the system of intermittent downward filtration at Merthyr Tydfil have appeared most important; and they have accordingly been investigated, the results appearing in Sections I., II., & VI. of this Report. A process known as Whitthread's patent has been also examined by experiment on a sufficiently large scale, and the result is given in Section III.

The Committee having reported upon the sewage-farms at Tunbridge Wells and Earlswood at the last Meeting of the Association, it was thought advisable to inspect them again, as the works were incomplete when the Committee last visited them.

The observations at Breton's Farm have been proceeded with uninterruptedly, and are described in Section VII. of this Report. It is only necessary to add here that these investigations have now extended over a period of more than two years; and the experience thus gained from the *continuous* records of the flow, and sampling for analysis, of the sewage and effluent water, of the application of the sewage to the various crops, of the results of such

application upon the produce grown, and the degree of purification effected n the sewage, will, it is hoped, prove valuable to sewer authorities and others interested in the question of sewage-farming. Being fully impressed with the importance of these investigations, the Committee has paid special attention to render them as complete as possible; but it is felt that to perfect them, especially as regards the important branch relating to the effect of the application of the sewage upon the crops grown, it will be necessary to continue them for, at least, some months longer. This cannot, however, be done unless further funds are placed at the disposal of the Committee. The large number of analyses already made for the Committee, together with the great expense of an assistant constantly at Breton's Farm, and the various other investigations undertaken, have now nearly exhausted the Special Fund contributed by the towns. In requesting its reappointment, the Committee begs to submit to the Council of the Association the desirability of placing it in a position to complete the long and anxious inquiry intrusted to it.

SECTION I.—*Deodorization of Sewage and precipitation of Solid Matters, as carried on under the Patent of Messrs. Weare and Co. at Stoke Union Workhouse.*

The attention of the Committee was specially directed to this process by the authorities of towns where the process had been discussed as a possible means of dealing satisfactorily with sewage; and although only in operation on a small scale, the Committee felt it desirable to investigate the results, such as they were, and accordingly an inspector was sent in September 1871 to the Workhouse at Stoke-upon-Trent. Every facility was afforded by the manager for the examination of the process, which was fairly conducted, and the Governor of the Union kindly gave the requisite particulars of the administration of the establishment.

The workhouse contains on an average 750 persons of all ages, whose diet comprises meat and vegetables, puddings, rice, and soup, each on certain days of the week. The supply of water fit for drinking and culinary purposes is very small, and is obtained principally from a well pumped by a steam-engine, and that for washing and scouring is taken from a pond, which is chiefly supplied by rain-water from roofs. Every department of the establishment is provided with water-closets, on the trough system, and they are emptied every 24 hours, and closely attended to in order to prevent interference by the inmates.

The process of purification of the sewage is protected by a patent. It consists, in the first instance, of simple filtration through coarse ashes and charcoal, performed in a large tank called the Fæcal Tank, which is divided into two compartments, so that one may be at work while the other is being cleared. These compartments are again subdivided into two chambers, one large and one small. The raw sewage is brought to a small receiver and from it turned, by means of sluices, into either compartment. The samples of sewage taken by the Committee's inspector were obtained from this receiver; the flow was ascertained to be about 5000 gallons in the 24 hours, being much below the capacity of the filters, which were constructed for 20,000 gallons per day. From the large chambers of the fæcal tank the sewage is passed through wooden screens, containing 2 feet of charcoal, into the small chambers, which contain about 5 feet 6 inches of rough charcoal, through which the sewage passes to a smaller tank or well, thus completing the first stage of filtration. The suspended matters are partly arrested by

the wooden and charcoal screens between the large and small chambers, and a further deposit takes place in the small chamber, which is cleared once in six months; but at the time of the Committee's inspection it had not been cleared for nine months, owing to the constant visits of persons anxious to inspect the process. Samples of the sewage at this stage of the process were duly taken. From the tank or well before described, the sewage (after again passing through a perforated screen containing 6 inches of rough charcoal) is conveyed by a 12-inch pipe to the "Deodorizers," which are, in this case, at some distance from the fæcal tank.

The "Deodorizers" are three in number,—the first and largest having a surface area of nearly 200 square feet, and containing 5 feet 6 inches depth of rough charcoal; the second, with an area of about 70 square feet, contains 2 feet 6 inches of charcoal of smaller size; the last is a small box containing 4 feet of fine charcoal, which is in this instance supplemented by layers of flannel and filter-cloth. It was stated, however, that cloth is not a necessary addition if the tanks are specially constructed, in which case the last deodorizer is arranged for upward filtration. This completes the process, the effluent water being discharged into a small well, from which the samples were taken for analysis.

The charcoal used at the time of the Committee's inspection was wood-charcoal; but it was stated that it was proposed to use peat-charcoal. The practice is to remove the "spent" charcoal from the last deodorizer to the second one, from the second to the first, and from the first deodorizer to the fæcal tank. Samples were taken of charcoal from each deodorizer after various periods of service, and analyses of them and of unused charcoal are appended.

The flow of effluent water for the period of twenty-four hours, during which continuous gaugings were taken, amounted to about 2000 gallons only, as against 5000 gallons of sewage received into the fæcal tank during the same period. The deposit removed from the tanks with the refuse of the establishment is utilized upon the farm belonging to the Union, which is cultivated entirely by the inmates.

The following are the results of the analyses of the different samples of sewage, effluent water, and charcoal:—

Stoke-upon-Trent Union Workhouse Sewage, Messrs. Weare's Process. Samples taken September 1871.

N.B.—Samples taken every two hours during the day, in the proportion of $\frac{1}{1000}$ of the flow per minute. Results given in parts per 100,000.

Description of samples.	Solid Matter.				Chlorine.	Nitrogen.						Remarks (by Dr. Russell).
	In solution.		In suspension.			In solution.				In suspension.	Total in solution and suspension.	
	Dried at 100° C.	After ignition.	Dried at 120° C.	After ignition.		As ammonia.	Organic.	As nitrates and nitrites.	Total.			
Sewage from receiver before treatment	163·80	87·50	171·40	59·45	28·12	24·01	4·94	..	28·95	9·5	38·45	
Sewage after passing through "fæcal tank" filters	85·70	56·50	8·05	1·50	14·91	9·76	0·63	...	10·39	1·27	11·66	
Effluent water after passing through deodorizing tanks	68·00	54·40	...	...	11·20	2·15	0·63	None	2·78	..	2·78	Had strong smell [of sewage.

Analyses of Samples of Charcoal from Stoke Union Workhouse.

	In 100 parts.	
	Water &c dried at 100° C.	Ammonia.
Charcoal before use	24·20	0·0014
Charcoal after five weeks' use in No. 3 deodorizing tank, to be applied to No. 2	50·12	0·0018
Charcoal after two months' use in No. 2 deodorizing tank, to be applied to No. 1	55·61	0·045
Charcoal after five months' use in No. 1, to be applied to fæcal tank	54·12	0·082

With regard to the analyses, the Committee would observe, in the first place, that the sewage treated was excessively strong, containing no less than 38·45 parts of nitrogen (in solution and suspension) in 100,000 parts of sewage; this is accounted for by the very scanty water-supply, from which it results that the amount of sewage is only $6\frac{2}{3}$ gallons per head in the twenty-four hours.

The general result of the process is that the suspended matters are removed and the ammonia and organic nitrogen much reduced in quantity; no oxidation takes place, as no nitrates were found in the effluent water, which was to all intents and purposes a dilute sewage and "had a strong smell of sewage."

It is remarkable that the chlorine is reduced to just about half its original amount; and it is still more remarkable that this should take place almost entirely in the first or fæcal tank: this reduction would seem to imply that a very considerable dilution must in some way take place; and notwithstanding this we find that there were only 2000 gallons of effluent water to 5000 gallons of sewage in the twenty-four hours, indicating an unexplained escape of three fifths of the total amount, even supposing that there was no dilution.

The amount of water absorbed by the charcoal, although, as indicated by the analyses, considerable, does not of course in any appreciable degree account for such a loss.

SECTION II.—*Deodorization of Sewage and precipitation of Solid Matter, and conversion of Solids into Cement, at Ealing.*

The district of the Local Board of Health of Ealing contains 1222 acres, and is situated near the river Thames, into which it drains, the sewer outlet being into a small watercourse about a mile from that river. The Board has executed a complete system of sewerage, and water-closets are general in the district. The population is about 8000, and the ordinary or dry-weather quantity of sewage discharged 400,000 gallons daily. The first system for the deodorization of the sewage was that proposed by the Surveyor to the Board (Mr. Jones), and consisted in bringing the sewage to two ingeniously constructed depositing-tanks, where it subsided, and the supernatant water was then passed upwards through 7 feet of filtering media, the solid deposit being mixed with ashes, dust, &c., and sold for manure.

In 1868 and 1869 the Rivers Pollution Commissioners made an examination of this process; and they very carefully inquired into the various

operations, and especially as to the construction, size, and action of the tanks. They had analyses made of the sewage and effluent water, and compared the quantity of the sewage with the capacity of the filtering media, and in all respects fully investigated the matter; and they came to the conclusion, which the analyses proved, that the process did not fulfil the conditions of purifying sewage, so as to render it fit to be discharged into running streams. They particularly remarked upon the amount of filtering media not being of sufficient bulk for the purpose.

The following are the results of the analyses as contained in the Report of the Rivers Pollution Commissioners:—

Treatment of Ealing sewage by upward filtration.

Results of analyses expressed in parts per 100,000, and including both suspended and dissolved matters.

Description.	Total solid matters.	Organic carbon.	Organic nitrogen.	Ammonia.	Nitrogen as nitrites and nitrates.	Total combined nitrogen.
Sewage as delivered at works April 24th. 1868	115·5	27·848	2·930	7·000	·000	8·695
Sewage flowing from last filter April 24th. 1868	78·5	6·093	2·785	4·250	·076	6·361

Since this inquiry a series of experiments has been conducted by Genera Scott with the sewage of the same place, which the Committee has considered of sufficient promise to justify an inquiry into the results as far as they have hitherto gone.

The principle of General Scott's process is to arrest the flow of the sewage by tanks, the suspended matters being precipitated by means of lime and clay, which are added to the sewage in the sewer previous to its arrival at the tanks, the proportion of lime so added being about 10 cwt., and of clay 5 cwt. to 400,000 gallons of sewage. After the sludge has sufficiently accumulated in the tanks it is drawn off, placed in a kiln and burnt by intense heat, and then ground into cement.

The effluent water passes off very much clarified, and without any offensive smell at the time of discharge.

The burning of the deposited matter, with the mixture of the lime and clay, renders the cement perfectly inodorous, and is one of the means by which the difficult question of the disposal of the precipitated sludge from sewage may be solved; and the method is one which may be adopted in cases where sewage cannot be used for irrigation in its crude state.

The chief points which are insisted upon in this case are:—

"1st. The more intimate mixture which can be brought out in the "sewage-water, owing to the impalpable nature of the precipitate of "carbonate of lime which takes place on the addition of the lime.

"2nd. The more rapid settlement of the sewage-precipitate than the "mixture of chalk and clay.

"3rd. The amount of organic matters which is carried down from the "sewage with the carbonate of lime and clay, and which serves for "the fuel to burn the mixture into lime or cement."

The amount of fuel which sludge will yield is stated to be so large that, in

the absence of any better mode of getting rid of it, and in consequence of the loss which results from attempting to deal with it as a manure, it has even been proposed to destroy it by burning.

The Committee inspected the works at Ealing in September 1871. On that occasion it was found that General Scott's process was not in operation, although he was treating the sewage experimentally with deodorizers. It was decided therefore to test the existing system of treating sewage by upward filtration; and for this purpose it was arranged that General Scott should not apply deodorizers to the sewage during the sampling &c. by the Committee. It appeared, however, that the Local Board kept a man at the upper end of the town mixing deodorizers with the sewage every day (except Sunday). The deodorizing-mixture was being added to the sewage at the rate of 20 gallons an hour, but its composition was not stated. Samples were taken on behalf of the Committee:—1st, of the sewage as it entered the works; 2nd, of the sewage after leaving the precipitating-tank; 3rd, after passing through the first filter; 4th, after passing through the second filter. The samples were taken six times during the day, the quantity taken being proportioned to the flow at the time. It was further deemed advisable to ascertain the effect of the deodorizing-mixture added by the Local Board; and for this purpose arrangements were made that nothing should be added on a certain day, when samples of the sewage and of the effluent water at the outfall were obtained. The analyses of the six samples will be found below; and it will be seen that the results confirm the investigations of the Rivers Pollution Commissioners, and that the process does not render the sewage fit to be discharged into running streams.

The next investigation by the Committee took place in March 1872, when the sewage works were wholly under General Scott's control. On this occasion gaugings were taken which confirmed the previous statements of the daily discharge of sewage being about 400,000 gallons. The samples were taken every two hours, in the proportion of $\frac{1}{1000}$ of the rate of flow. The gaugings and samplings extended over five days, and the analyses made for the Committee by Dr. Russell are given below.

A further inspection of the works was made last month (July) during very hot weather, when it was found that the process was proceeding without any nuisance whatever, although the depositing-tanks are clearly not of sufficient capacity, a defect which it is intended to remedy. The effluent water, after leaving the depositing-tanks, contains some suspended matter, and has a scum on its surface which can only be got rid of by filtration. It is proposed to filter it with this view; but the liquid will still contain the soluble organic impurities (see remarks on analyses), which can only be reduced in quantity by filtration through soil by means of irrigation, for which the effluent water of Ealing is well adapted.

The open ditch, before referred to, which conveys the deodorized sewage from the outfall to the Thames, was carefully examined on this occasion, but not the slightest smell was detected; the water has, however, a yellow tinge, from a slight precipitate which it deposits along the line of the ditch. This is no doubt due to the insufficient capacity of the depositing-tanks, the increase of which will probably effect an improvement.

One of the difficulties attending the process as now conducted, is the drying of the precipitated sludge with sufficient rapidity. If this is done by heat, it is liable to cause a nuisance, being by far too slow in action even at Ealing, with only about 2 tons of sludge daily. It is proposed in this case to force the water out of the sludge by means of Needham and Kite's hydraulic

press, which will at once render the solid matter nearly dry enough to burn into cement.

On the whole this process, when perfected, promises well as a means of treating one of the difficulties of the sewage question—the disposal of the sludge precipitated from sewage. It appears not only possible to destroy the solid matters by fire, but also to secure some return from their use in the manufacture of cement.

Remarks on the Analyses of Sewage and Effluent Water from Ealing.

Ealing sewage, upward-filtration process. Samples taken 5th and 6th September, 1871.

N.B.—Samples taken every two hours during the day, in the proportion of $\frac{1}{100}$, of the flow per minute. Results given in parts per 100,000.

Number.	Description of samples.	Average temperature of samples.	Solid matter. In solution. Dried at 100° C.	Solid matter. In solution. After ignition.	Solid matter. In suspension. Dried at 120° C.	Solid matter. In suspension. After ignition.	Chlorine.	Nitrogen. In solution. As ammonia.	Nitrogen. In solution. Organic.	Nitrogen. In solution. As nitrates and nitrites.	Nitrogen. In solution. Total.	Nitrogen. In suspension.	Nitrogen. Total in solution and suspension.	Remarks.
		°F.												
1.	Sewage as it entered works..............	62·0	70·50	10·10	65·50	39·30	12·28	5·10	0·51	...	5·91	2·19	8·13	Taken Sept. 5, when deodorizing-mixture had been added by Local Board as usual.
2.	Sewage as leaving precipitating-tank.	60·0	72·40	11·90	16·50	3·90	11·86	6·48	0·76	.	7·21	1·37	8·61	
3.	Sewage after passing through No. 1 filter	60·0	71·00	46·70	15·20	3·35	10·79	5·64	1·16		6·80	0·89	7·69	
4.	Sewage after passing through No. 2 filter	60·0	70·30	40·80	9·80	3·10	9·73	5·60	..		5·60	trace	5·60	
5.	Sewage as it entered works	..	71·60	39·60	97·15	35·50	10·37	7·41	1·31	.	8·72	1·12	13·11	Taken Sept. 6, when no deodorizing-mixture had been added to sewage.
6.	Sewage from outfall, after passing thro' filter	..	65·80	41·40	20·70	8·60	10·11	6·75	0·60	...	7·35	0·97	8·32	

Ealing sewage, General Scott's process. Samples taken March 26th to April 5th, 1872.

N.B.—Samples taken every two hours during the day, in the proportion of $\frac{1}{1000}$ of the flow per minute. Results given in parts per 100,000.

Description of samples.	Average rate of flow per minute.	Average temperature of samples.	Solid matter. In solution. Dried at 100° C.	Solid matter. In solution. After ignition.	Solid matter. In suspension. Dried at 120° C.	Solid matter. In suspension. After ignition.	Chlorine.	Nitrogen. In solution. As ammonia.	Nitrogen. In solution. Organic.	Nitrogen. In solution. As nitrates and nitrites.	Nitrogen. In solution. Total.	Nitrogen. In suspension.	Nitrogen. Total in solution and suspension.	Remarks.
	gals.	°F.												
Sewage collected from main sewer in town	290	17·5	61·60	15·00	90·28	62·18	6·31	2·86	0·75	.	3·61	2·98	6·59	There had been rain for some days previous to the sampling.
Effluent water from outfall	.	46·0	51·40	12·40	...	...	1·62	·79	1·41	·53	2·73	..	2·73	A small amount of suspended matter present. Sample not filtered.

From these analyses it will be seen that the upward-filtration process, whether accompanied or not by the previous addition of the deodorizing-

mixture, effected only a very slight purification of the sewage, which left in the filters still a sewage of average strength; it was not even clarified. With regard to General Scott's process, it would appear that by it the suspended matters are precipitated very completely: as to the more important constituents of the sewage, it is seen from the analyses that the effluent water contained rather more than two thirds of the chlorine, and three fourths of the dissolved nitrogen of the sewage; but it must be remarked that the dissolved nitrogen appears in a different way in the effluent water and in the sewage; the actual ammonia is reduced to one quarter of its amount, while the organic nitrogen, doubtless from solution of some of the nitrogenous suspended matters, is nearly doubled in amount in the effluent water. Some oxidation, too, has taken place by which nitrates appear in the solution. Such water would be much too impure to be sent into a river, and too valuable to be wasted; indeed it is not pretended that the process is capable of *purifying* the liquid sewage, its object is merely the separation and deodorization of the sludge (which, in the majority of cases, must necessarily be removed before the sewage can be utilized), and its ultimate use as fuel in the manufacture of cement.

Section III.

A process known as "Whitthread's Patent" having been brought under the notice of the Committee, has been investigated by a preliminary experiment on a sufficiently large scale, although it is not at present in operation anywhere, the supporters agreeing to pay the expense of the necessary analyses.

The process consists in the addition of a mixture of dicalcic and monocalcic phosphate containing, it was stated, two equivalents of dicalcic to one of monocalcic phosphate (the latter being added as commercial superphosphate), and then afterwards a little milk of lime. In the experiment referred to 100 gallons of sewage, taken from the Romford sewer before it joins the tanks on Breton's Farm, were operated on, one pound of the mixture being stirred up in a little water, and added after the addition of a little milk of lime. The precipitation was very rapid, and the supernatant water remained very nearly clear and quite inoffensive.

The accompanying Table shows the result of the analyses of the raw sewage, the supernatant water, and the precipitate:—

Results given in parts per 100,000.

Description of samples.	Solid matter. In solution. Dried at 100° C.	Solid matter. In solution. After ignition.	Solid matter. In suspension. Dried at 120° C.	Solid matter. In suspension. After ignition.	Chlorine.	Nitrogen. In solution. As ammonia.	Nitrogen. In solution. Organic.	Nitrogen. In solution. As nitrates and nitrites.	Nitrogen. In solution. Total.	Nitrogen. In suspension.	Nitrogen. Total in solution and suspension.	Remarks (by Dr. Russell).
Sewage sample from 100 gallons as it entered the tanks	71·20	41·40	21·14	9·68	11·57	2 28	0·90	...	3·18	1 93	5 11	
Supernatant liquid filtered ..	83 8	56·2	...	...	11·21	2·50	0·02	none.	2·52	...		$P_2O_5=5·53$.

Examination of the precipitate after drying it at 100° C.

Results in 100 parts.

Ammonia	3·03
Phosphoric acid (P_2O_5)	8·18
Lime (CaO)	23·51
Phosphate of alumina and iron	5·94
Loss on ignition	32·86
Residuum, insoluble in hydrochloric acid	14·54

We have said that the suspended matters were in very small amount in the supernatant water; this is evidently merely a question of time allowed for settling. It will be seen that the amount of ammonia in solution is somewhat greater in the effluent water than in the sewage, doubtless from the decomposition of some of the soluble organic matter in solution; but the most remarkable thing is that the organic matter in solution was almost entirely removed in this experiment, so that while the sewage contained 0·90 part of organic nitrogen in solution in 100,000 parts, the supernatant water only contained 0·02 part. It must, however, be distinctly understood that this is only a preliminary experiment, from which general conclusions must not be too hastily drawn. The supernatant water contained a considerable quantity of phosphoric acid, viz. 5·53 parts in 100,000.

The analysis of the precipitate shows it to contain a large proportion of phosphate of lime; and its value is much enhanced by the three per cent. of ammonia which it also contains.

The presence of phosphoric acid in the supernatant water would be of considerable advantage if this were afterwards used for irrigation, but, unless means are devised for separating it, would constitute a serious loss if the water were thrown away.

On the whole, then, this preliminary experiment shows that the process in question well deserves further and careful investigation.

Section IV.—*Additional Note on the Dry Earth system.*

In the last Report the Committee gave the results which Dr. Gilbert had obtained from the analysis of soil which had been used in an earth-closet either once or twice.

It appeared that, "calculated upon the air-dried condition, the increase in the percentage of nitrogen was only about 0·15 each time the soil was used; and, even after using twice, the soil was not richer than good garden-mould."

From two agreeing determinations Dr. Gilbert now finds that soil which has been used three times in the closet contains, when dried at 100° C., only 0·446 per cent. of nitrogen; and duplicate determinations entirely confirmed this result, so that we have the following series:—

	Before used.	After using once.	After using twice.	After using three times
Percentage of nitrogen in soil dried at 100° C.	0·073	0·210	0·383	0·446

So that the remark made by the Committee last year with regard to soil which had been used twice, "that such a manure, even if disposed of free of charge, would bear carriage to a very short distance only," is applicable also to soil which has been used three times in the earth-closet.

SECTION V.—*Sewage-Farms.*

a. EARLSWOOD SEWAGE-FARM.

It will be remembered that the Committee investigated the utilization of the sewage of Redhill, Surrey, at Earlswood Common, and reported the result at the last Meeting of the British Association at Edinburgh. In this Report the extent and mode of laying out the land and applying the sewage were described, and analyses were given of samples of the sewage and effluent water taken by the Committee. The results of these analyses showed that the sewage, although very weak, was but very imperfectly purified by the process; and that this was so, was attributed by the Committee chiefly to the absence of underdrainage in the irrigated land, the analyses and various observations as to the temperatures of the samples pointing to the conclusion that the land had become saturated, and that the sewage simply flowed over it instead of percolating through it.

The Committee has again examined this farm, considering it desirable to ascertain and report any change of circumstances connected with it. No sampling of the sewage or effluent water was made on this occasion, as it was found that the farm remained very much in the same condition as when last visited.

The outfall ditch, which receives the effluent sewage from the lowest beds, has been lowered 2 feet, so as to admit of subsoil-drainage over the whole farm; but none has been executed, although the idea was at one time entertained.

The sewage is still passed through "Latham's patent extractor;" but the result is only to disengage a very small amount of solid matter, and it requires the attendance of one man daily.

The land has been taken as a sewage-farm for the sewage of Reigate as well as that of Redhill; but the sewage from the former place is not yet conveyed to the farm, the sewer, which was in course of construction last year, being still incomplete.

The flow of sewage and effluent water was found to be about equal in quantity, viz. 250 gallons per minute. Looking at the results of the present system, with the sewage of Redhill only, the effect of adding that from Reigate cannot be expected to be satisfactory, unless improvements are made in the mode of laying out the land, and unless it is properly underdrained.

The crops on the farm consist principally of rye-grass and oats, with a few mangolds. The rye-grass, of which three crops have been cut this year, is for the most part made into hay, there not being sufficient demand for it in the green state. It should be stated that on the occasion of this inspection the effluent water was running apparently clear and free from smell.

b. TUNBRIDGE WELLS SEWAGE-FARMS.

The Committee also deemed it desirable to inquire what had been done at these farms since the investigation last year.

It will be remembered that the sewage of Tunbridge Wells, which is tolerably concentrated, is conveyed by gravitation to two farms, one situated on the north, and the other on the south of the town. The farms were not uniformly underdrained, but some previously existing drainage was employed under a peculiar system to redistribute the effluent sewage-water. The distribution was effected by the catchwater system, the sewage-sludge being previously allowed to subside in tanks constructed for the purpose.

Analyses of the samples taken on the first inspection of the Committee showed that the purification effected was, on the whole, unsatisfactory, especially on the south farm.

No samples were taken at the recent inspection of the farms, it being desired principally to ascertain their present working condition. On visiting the north farm it was found that the sewage was running into the tanks at the rate of 280 gallons per minute. It was muddy, and smelt very strongly. The effluent water appeared to be running clear and free from smell, and the stream into which it is discharged was clearer than it was at the last inspection. Some additional catchwater-drains had been put in, and some defective subsoil-drains repaired; but, as far as could be learned, no regular system of subsoil-drainage had been commenced. The crops on this farm consisted of meadow-grass, Italian rye-grass, mangolds, oats, beans, and wheat, and were generally in excellent condition; but the rye-grass is not so strong as it was last year, probably owing to this being the third year after sowing. There is plenty of demand for it at 1*s.* per rod green; and about 1000 cubic yards of hay, of very good quality, had been made from it this year. The other crops are described as very heavy. It was stated that a large field of turnips, being infested with the fly, was flooded with sewage, which drowned the fly and saved the crop, which is expected to turn out well, but rather late. The wheat was sewaged twice during the spring, and was a very fine crop, the Committee's Inspector computing the probable average yield at about seven quarters per acre. The whole farm was described as looking better and in a healthier state than last year.

On the south farm the sewage was running into the tanks at the rate of 440 gallons per minute, and it smelt very offensively. The effluent water was very clear and free from smell. The crops on this farm were also looking very well, but not generally so fine as those on the north farm. The rye-grass here, as at the other farm, was not so strong as last year, from which it would appear that three years is too long to grow and cut from the same roots. There were about ten acres of wheat, four being on sewaged ground, and six manured with the sediment from the tanks, both looking equally well. Some hops which received sewage in the winter compared very favourably with others which are too high above the carriers to be sewaged, being stronger in the bine and of a darker green colour. A field of beans was noticed, one portion of the crop being very heavy and healthy-looking, and the other very poor and stunted. On inquiry it was ascertained that the whole field had been equally sewaged, but that the portion where the crop was so good had been drained 4 feet deep during last winter, the other portion being left undrained. It seems desirable to call attention to this circumstance, as affording further proof of the necessity (already insisted upon by the Committee in a previous Report) of subsoil-drainage in connexion with sewage irrigation. It was stated that there was a ready sale for the green crops produced on this farm. The rye-grass is appreciated by the local cow-feeders, who say that their cattle thrive well on it. Judging from the experience of these farms, it would also appear that sewage irrigation is, when properly managed, as well adapted for grain crops as for green crops; but the quantity which can be applied to them being comparatively very small, the area for the distribution and application of the sewage must be greatly increased in proportion as corn crops are grown by its aid.

SECTION VI.—*Merthyr Tydfil Sewage-Farm at Troedyrhiw.*

In January last the attention of the Committee was directed to a system of purifying sewage by intermittent downward filtration which was then completed at Troedyrhiw, near Merthyr Tydfil, for dealing with the sewage of the latter place.

In 1870 the present Rivers Pollution Commissioners, in their first Report, described some most important experiments which had been conducted in their laboratory by Dr. Edward Frankland, F.R.S., which satisfactorily proved that intermittent downward filtration (which is, in fact, irrigation confined to a small area), "properly conducted, is a most efficient means of purifying sewage." The various trials with different soils showed conclusively that town sewage might in this manner be cleansed and rendered sufficiently innocuous for discharge into streams. The Commissioners stated that an acre of filtering material 6 feet deep would so cleanse the sewage of 3300 people; but they expressed an opinion that, whilst successful from a remedial point of view, the system would be very wasteful, as not utilizing the valuable manurial properties of sewage; and for this reason it was only to be recommended for employment on a small scale, or where circumstances rendered other processes difficult and expensive.

In 1868, and again in 1869, injunctions were granted by the Court of Chancery to prevent the Local Board of Merthyr Tydfil from discharging the sewage of that town into the river Taff.

Merthyr Tydfil contains a population of 50,000; but, according to information supplied to the Committee, the excretal refuse of not more than two fifths of this number is discharged into the sewers, although the slops and other liquid refuse from a further like number (20,000) is stated to be admitted. It is not surprising, therefore, that the sewage is, as afterwards appears, exceedingly weak.

In 1870 the Local Board gave notice for the purchase of 393 acres of land in the valley of the Taff, upon which to dispose of the sewage. Of this quantity 70 to 80 acres were purchased below the village of Troedyrhiw, which is about three miles from Merthyr Tydfil; and it is here that an area of about 20 acres has, under the supervision of a member of the Committee, been converted into a filter-bed for the practice of the system of downward filtration originated by the Rivers Pollution Commissioners, as above described.

The soil of this area consists of a deep bed of gravel (probably the former bed of the river Taff, which is embanked upon the east side, and is raised above the valley), composed of rounded pebbles of the Old Red Sandstone and Coal-measure formations, interspersed with some loam and beds of sand, forming an extremely porous deposit, and having a vegetable mould on the surface.

The land has been pipe-drained at a depth of less than 7 feet, and the pipes are concentrated at the lowest corner, where the effluent water is discharged into an open drain, which leads to the river Taff at some distance down the valley.

The area is laid out in square beds, intersected with roads and paths, along which are constructed the main carriers which receive the sewage from the outfall sewer and distribute it over the beds.

The sewage before entering the farm is screened through a bed of "slag," which arrests the coarser matters. It is applied to the land intermittently; for the area being divided into four plots or beds, it is turned on each one

for six hours at a time, leaving an interval of eighteen hours for rest and aëration of the soil.

The surface of the land was cultivated to a depth of from 16 to 18 inches, and laid up in ridges in order that the sewage might run down the furrows, while the ridges were planted with cabbages and other vegetables.

The Committee has adopted the same mode of investigation in this as in other cases, and the following is a description of their operations.

It was thought advisable in this, as in other examinations of sewage-farms, that inspections should be made at two seasons of the year,—in winter, when the land is saturated with rain or frozen, and again in summer during dry weather, when there is the greatest activity in vegetable life.

The first examination of the farm was made in January last, in very wet weather, when the system was in operation as above described. Samples, extending over a period of seven days, were collected of the sewage as it entered the farm, and of the effluent water from the outfall drain before described. Gaugings were taken of the flow of both the sewage and effluent water for eight days, with the following results:—

Date.	Temperature.				Average flow per minute.		Remarks.
	At noon.		Average during day.				
	Air.	Ground	Sewage	Effluent water.	Sewage.	Effluent water.	
	° F.	° F.	° F.	° F.	gals.	gals.	
Jan. 9	...	...	49	46	757	1424	Showery.
10	50	49	49	46	784	1687	Continuous rain.
11	49	48	50	47	844	1875	Showery.
12	48	46	48½	45	875	1940	Light rain day; heavy at night.
13	49	47	47	45½	1119	2538	Continuous heavy rain.
14	50	49	48	46	630	1560	Fine.
15	40	38	43	45½	720	1424	Misty.
16	37	39	15	46	730	1150	(Only two gaugings taken)
			Average .		807	1699	

It will be seen that the quantity of effluent water discharged was more than double the quantity of sewage; and as the rainfall, though considerable, could not possibly account for such an increase, it was felt necessary to look elsewhere for its cause. It was ascertained from the Surveyor to the Local Board that the bed of the river Taff is 4 feet 7 inches above the bottom of the effluent drain; and observation proved that when the water in the river rose that of the drain rose also, and on the river-water subsiding the same thing occurred in the drain. From this it became evident that a filtering communication exists between the river and the drains, the nature of the soil rendering this very probable. To further test the matter, trial holes were dug in a field adjoining, and to the north of the filtering-beds, when it was found that the same thing occurred, the water collected in them rising and falling with that in the river.

It should be stated that some gaugings of the flow of the sewage were taken in November 1871, by Mr. Harper, the Surveyor to the Local Board, which, as will be seen, agree closely with those taken for the Committee.

1871. Nov. 14 and 15. Rain part of the time.

Greatest flow	. . . .	1075 gallons per minute.
Least "	. . . .	768 " " "
Average flow for the two days	.	925 " " "

1871. Nov. 30 and Dec. 1. Dry weather.

Greatest flow	. . . .	768 gallons per minute.
Least "	. . . .	631 " " "
Average flow for the two days	. .	728 " " "

824,796 gallons per day is the summer dry-weather flow of the sewage from the whole of the district.

The second examination was made by the Committee in the early part of July last, when samples and gaugings were taken for a period extending over eight days. The samples were taken, as in the previous case, at the rate of $\frac{1}{10,000}$ part of the flow at the time of taking. The following are the results of the gaugings on this occasion:—

Date.	Temperature. At noon. Air.	Temperature. At noon. Ground	Temperature. Average during day. Sewage.	Temperature. Average during day. Effluent water.	Average flow per minute. Sewage.	Average flow per minute. Effluent water.	Remarks.
July	° F.	° F.	° F.	° F.	gals.	gals.	
2.	70	63	60	56	925	1600	Rain early in morning.
3.	70	64	60	55	740	1450	Dry.
4.	75	73	60	55	630	1425	Dry.
5.	69	70	60	56	630	1425	Dry.
6 A.M.	68	70	55	68	630	1425	Dry till 11 A.M.
6 P.M.					2600	2604	Thunderstorm at 11 A.M.
7.	68	64	60	55	4000	4000	Rain in morning and all previous night.
8.	68	44	60	55	925	1800	Slight rain in morning.
9.	68	50	60	55	780	1700	Dry after 7 A.M. Slight rain previous night.
			Average.....		1318	1936	

The samples of sewage and effluent water taken were collected only during the dry portion of the above period, namely, the afternoon of the 2nd July, all the 3rd, 4th, and 5th, the morning of the 6th, and the afternoons of the 8th and 9th, when the rains could not be said to have had any effect on them, and they may be considered fair samples of the dry-weather sewage and effluent water. Selecting the entirely dry days from the above, it would appear that the ordinary flow of dry-weather sewage may be stated as 650 gallons per minute, and that of the effluent water at 1425 gallons per minute. Allowing one fourth of the sewage to be evaporated during dry weather, it would appear that the effluent sewage is diluted during dry weather with about twice its bulk of comparatively pure water from the river and other sources.

The thunderstorm which occurred on the 6th July afforded further proof of the connexion between the river-water and that of the effluent drain. On the morning following the storm the water in the river had risen 7 feet 6 inches perpendicular, and on walking along the bank the Inspector found the river-water percolating through and flooding the ground 18 inches deep. The water in the effluent drain was 3 feet 6 inches deep, and was estimated to be running at the rate of 3500 to 4000 gallons per minute.

The surface of the filtering areas was prepared for cultivation in the spring of 1871, and in June of that year cabbages were planted and mangolds sown; and the crops were sold in the autumn, yielding very good prices. As soon as cleared they were replaced by others, some of which are now in the ground, and some have been sold at high prices.

The adjoining land at Troedyrhiw, belonging to the Local Board, has been cultivated as a sewage-farm proper with complete success, the crops grown being of a high class. The Board also intends to apply the sewage to the land before referred to in the valley of the Taff, but has reduced the quantity previously intended to be taken by 112 acres, since the success of the downward-filtration system has been demonstrated. It will of course be understood that this latter system is in this case only intended to be used in conjunction with the ordinary sewage-irrigation; and, considered as a means for the disposal of the sewage, and especially of the night-sewage, there can be little doubt of the success of this method. But whether it would be equally favourable in other cases, when solely relied on for the disposal and purification of the sewage of other towns, and under all the different conditions as to soil, water, strength of sewage, &c., is a subject upon which there may be considerable doubt, but which is, nevertheless, a proper one for further investigation.

The Rivers Pollution Commissioners have recently presented another Report to Parliament, in which they describe the operations at Troedyrhiw; and they therein admit that the fears expressed in their first Report, that the manurial properties of sewage would be entirely lost in this process, and that the treatment of the sewage of a large town by it would probably result in a nuisance, have not been borne out in this case.

The Commissioners state:—"Our analyses show that the effluent water entering the Taff from the Merthyr intermittent filters was of even a more highly satisfactory degree of purity than the samples which we examined resulting from the process carried out on a small scale in our laboratory; but a comparison of the proportions of chlorine in the sewage and effluent water shows that the whole of the latter is not derived from the former. We find, in fact, that each gallon of the sewage, on June 19, 1871, had become mixed with 2·2 gallons of subsoil-water, and that on October 20, 1871, each gallon of sewage had become mixed with 1·9 gallon of subsoil-water. This result involves the assumption that the subsoil-water contained the same proportion of chlorine as that present in the water of the neighbouring Taff, which, according to our analyses, has 1·2 part of chlorine in 100,000 parts."

It will be seen that this opinion of the Commissioners, founded upon chemical analysis, more than confirms the conclusion of this Committee, based upon the results of the gaugings taken, that the effluent sewage is diluted with twice its bulk of comparatively pure water.

The Commissioners consider, nevertheless, that the net result of the action of the soil of the intermittent filters upon the sewage was highly satisfactory,

attention being drawn at the same time to the exceptionally weak character of the sewage; and bearing this in mind, they suggest that "it may be necessary, in order to secure efficient purification, to lay out as intermittent filters even double the area of land per 10,000 of population that is employed at Merthyr Tydfil, where only from two to five acres per 10,000 people were being employed."

The following are the analyses of the samples taken by the Committee:—

Sewage-Farm at Merthyr Tydfil. Analyses taken 10th to 15th January, 1872.

N.B.—Samples taken every two hours during the day, in the proportion of $\frac{1}{10000}$ of the flow per minute. Results given in parts per 100,000.

Description of samples.	Average temp. of samples.	Solid matter.				Chlorine.	Nitrogen.						Remarks (by Dr. Russell).
		In solution.		In suspension.			In solution.				In suspension.	Total in solution and suspension.	
		Dried at 100° C.	After ignition.	Dried at 120° C.	After ignition.		As ammonia.	Organic.	As nitrates and nitrites.	Total.			
	°F.												
Sewage from main sewer	48	45·60	10·[illegible]0	12·[illegible]8	6·77	1·65	0·81	0·[illegible]	...	1·10	0·[illegible]0	1·90	
Effluent water from outfall	46	32·40	29·25	...	..	2·48	0·01	0·02	0·59	0·67	.	0·65	
Subsoil-water from adjoining field, where sewage is not applied	42	18·85	16·85	.	..	0·92	0·008	0·01	trace	0·05	.	0·05	Hardness:— Temporary 3·78, Permanent 5·93; 9·71

Sewage-Farm at Merthyr Tydfil. Analyses taken 2nd to 8th July, 1872.

N.B.—Samples taken every two hours during the day, in the proportion of $\frac{1}{10000}$ of the flow per minute. Results given in parts per 100,000.

Description of samples.	Average temp. of samples.	Solid matter.				Chlorine.	Nitrogen.					
		In solution		In suspension.			In solution.				In suspension.	Total in solution and suspension.
		Dried at 100° C.	After ignition.	Dried at 120° C.	After ignition.		As ammonia.	Organic.	As nitrates and nitrites.	Total.		
	°F.											
Sewage as entering farm	60	44·80	31·80	13·12	4·98	5·53	1·328	0·29	...	2·12	0·48	2·60
Effluent water from outfall	55	35·70	30·80	..	..	[illegible]	0·077	0·039	0·402	.	...	0·518

With regard to the winter sewage, we see, from the decrease in the amount of chlorine in the effluent water, that in this case each gallon of the sewage had become mixed with 1·39 gallon of subsoil-water, containing ·92 of chlorine in 100,000 parts; this shows a smaller amount of dilution than that stated by the Rivers Pollution Commissioners, and so far agrees better with our gaugings as above recorded. It will be noticed that the Commis-

sioners considered the subsoil-water to contain as much chlorine as the water of the river Taff, whereas actual analysis of it shows it to contain only 0·92 against 1·2 of chlorine in the river-water. Had we taken the composition of the river-water as given by the Commissioners, the dilution would have *appeared* in this case to be 1·7 gallon of subsoil-water to 1 of sewage, instead of 1·39 to 1.

Now the total nitrogen in solution in 100,000 parts of sewage was 1·40, in the effluent water 0·65, and in the subsoil-water 0·05 (see Table). Again, one volume of this sewage, mixed with 1·39 volume of this subsoil-water, would give 2·39 volumes of water, containing exactly 0·67 part of nitrogen in solution in the 100,000 parts—that is to say, that the apparent diminution of the nitrogen in solution is, within a small fraction, entirely due to dilution with subsoil-water; and the nitrogen retained in the soil is equal to the amount in the suspended matters of the sewage, that is to say, rather more than a quarter of the total nitrogen.

What is most important, however, is that, although all the nitrogen originally in solution is lost, it is almost all oxidized; for about $\frac{12}{13}$ of the nitrogen in the effluent water is in the form of innocuous nitrates and nitrites.

In the summer the dilution with subsoil-water was, according to the gaugings, equal to about twice the volume of the sewage. As the chlorine in the subsoil-water was not determined in the summer, we can only say that the smaller proportion of total nitrogen in solution in the effluent water seems to confirm the results of the gaugings.

The effluent water this summer was not quite so pure as last winter, but still four fifths of its nitrogen was in the form of nitrates and nitrites.

It is to be noted that the sewage was cooled by its percolation through the soil, and especially so in summer.

The general results seem to be that by the process the suspended matters are removed, and the ammonia and nitrogenous organic matters in solution are almost completely oxidized, and escape in the effluent water as nitrates and nitrites; so that the sewage is satisfactorily purified, though the process cannot be looked upon as one of utilization.

Section VII.—*Breton's Farm, near Romford.*

It will be in the remembrance of the members of the British Association that the Committee has been conducting a series of observations on the application of the sewage of the town of Romford to this farm, both as to the purification of the sewage and its utilization as a manure; accordingly the observations and analyses recorded in previous years have been continued during the past year, and the results will be found in the accompanying Tables.

The Committee have, however, extended their observations still further during the past year, and have supplemented them by the particulars of the crops which have been grown on the farm during the twelve months from March 25th, 1871, to March 24th, 1872, both days inclusive. But to make this inquiry more complete, and of greater practical utility, the Committee made an alteration in the form of the analysis of the sewage and effluent water, so as to determine the total nitrogen.

The observations which were made in relation to the crops gave the following results:—

		tons.
The quantity of sewage from the town received on the farm from March 25th, 1871, to March 24th, 1872, inclusive, is, according to the gaugings		416,787
The quantity of effluent water returned from the land to the tanks and repumped, during the same period, is		52,466
The quantity of sewage, dilute or otherwise, which we have to account for is therefore		469,253
According to the cropping table the quantity of sewage applied to the cropped land (chiefly by pumping, but also to a small amount by gravitation) during the aforesaid period is	380,227 tons.	
Mr. Gooch (the adjoining farmer) was supplied with	4,131	
There was applied to the garden (which is not reckoned as part of the farm proper)..........	933	
Total quantity................	385,291 tons *utilized.*	

Leaving 83,962 tons, which quantity was run upon a plot of land at the lower part of the farm by gravitation and simply filtered, during periods when it could not be put on the farm, owing to further drainage-works being in progress.

From Table III. it appears that the 380,227 tons of sewage so used contained 21·0245 tons of nitrogen, and that the total amount of effluent water running from the subsoil-drains during the twelve months, viz. 195,536 tons (of which 52,466 tons were returned to the tank, and repumped with the sewage on to the land, and the remainder discharged into the river Rom), contained 2·2430 tons of nitrogen, or approximately one tenth part of that applied in the sewage.

It must, however, be remarked that the figures in the columns marked * are calculated from the results of the analyses of the sewage and effluent water during the corresponding period of the present year (1872), as the method of analysis employed before July 1871 did not give results in the same denomination as that now used.

The total amounts of nitrogen in the sewage and effluent water respectively were calculated from the results of the analyses during the various periods; and the *absolute* averages were, for the sewage 5·529 parts, and for the effluent water 1·147 part in the 100,000.

In Table IV. will be found a detailed description of the crops, arranged according to the plots into which the farm is divided. The figures in columns III., VII., X., and XI. are as exact as possible, but those in columns VIII., IX., and XII. are at the best only approximations. The figures in column VIII., from which those in columns IX. and XII. are deduced, profess to represent the quantities of sewage applied during the twelve months to the several crops and plots; but it is obvious that with the means at the disposal of the Committee no precise measurements of these quantities could be obtained; for to gauge the quantities of sewage applied at various times to twenty-four plots with separate subdivisions, each having its own conduit, would require a preliminary outlay in plant estimated at £500, and the constant services of four additional educated assistants at probably not less than £250 a year each. The only way, therefore, that even approximate figures could be obtained for this column was by recording the number of acres to which the measured daily total quantity of sewage was applied, and assuming

that it was *equally distributed* over those acres—an assumption which, although giving a fair average approximation in the totals, necessarily often gives fallacious results in the particular instances, because, while some portions of the land had been consolidated by previous dressings of sewage, other portions sewaged at the same time were loose and hollow from recent cultivation, and therefore absorbed very much greater quantities of sewage.

Table V. gives a summary of the totals of Table IV., and in addition the approximate estimates of nitrogen corresponding to the approximate estimates of sewage, and also the amounts of nitrogen contained in the various crops, as calculated from proportions given by the best authorities. In all cases, however, the grand totals may be relied upon, as where they were not obtained by actual measurement they are (as, for instance, in the case of the weights of crops) the ultimate results of a very large number of carefully obtained averages.

Table VI. is also a summary of Table IV., but arranged according to the crops instead of according to the plots. It will be at once seen, from the remarks already made, that the separate total amounts of sewage, and therefore of nitrogen, assigned to each crop are much less reliable than the corresponding numbers for the plots; but, as in the last case, the grand totals (which are, of course, identical with those in the corresponding columns of the previous Table) are either absolutely correct or very reliable.

The important result to be deduced from the grand totals in these Tables is, that of every 100 parts of nitrogen distributed over the farm during the twelve months, 10·67 parts, or about one tenth, were found in the effluent water; 41·76, or approximately four tenths, were recovered in the crops, making together about half; and 47·57 parts, or in round numbers the other half, were unaccounted for. Of this half a portion must have remained in the soil; and as the average composition of the soil previously to the application of the sewage was determined by the Committee (see Second Report, to the Meeting at Liverpool), it is intended to determine the proportion of this unaccounted-for nitrogen which actually does remain in the soil at various depths.

The Committee thinks it right to call attention prominently to the fact that the above proportions (representing the manner in which the nitrogen of the sewage was ultimately disposed of in the case of Breton's Farm, during the twelve months to which the Tables refer) are, for the sewage and effluent water, as absolute and exact as accurate gauging and careful analysis can make them, and are, for the crops, calculated by means of the most reliable published data; they are, moreover, the final results obtained from a much greater number of continuously applied observations over a greater area, and with a much greater variety of crops, than have ever hitherto been scientifically made.

The two main results of practical importance which, from the evidence of the observations, may be accepted as generally attainable are:—first, that less than eleven per cent. of the total nitrogen applied to the land escaped in the effluent water, and of that only a fractional percentage in an organic form; and, secondly, that upwards of forty per cent. was actually recovered in the crops grown upon the land—a proportion which must be considered highly satisfactory (especially when the extreme porosity of the soil and limited area of the land are taken into account), as in the experiments of Messrs. Lawes and Gilbert only from forty to sixty per cent. of the nitrogen applied in solid manures was recovered in the crops within the season of application.

TABLE I.—*Breton's*

Statement of Weekly Quantities of Sewage received on the Farm, of Sewage or Effluent Water escap-

[Continued from

Number of weekly return.	Date (inclusive).	Average noonday temperature (air).	Rainfall during week.	Quantity of sewage delivered to the farm from the town.	Average temperature thereof.	Quantity of effluent water flowing out of the drains.
	1871.	° F.	in.	galls.	° F.	galls.
58.	July 16 to July 22	71	......	1,409,400	64	824,700
59.	July 23 to July 29	66	0·56	1,760,000	63	896,900
60.	July 30 to August 5.........	60	0·40	1,549,600	63·5	634,600
61.	August 6 to August 12 ...	77	......	1,462,500	66·5	670,200
62.	August 13 to August 19 ...	75	0·85	1,708,900	67	652,300
63.	August 20 to August 26 ...	69·5	0·07	1,560,400	67	617,500
64.	August 27 to Sept. 2	72·5	......	1,610,400	66	495,700
65.	Sept. 3 to Sept. 9	68	0·92	1,752,400	66·5	631,100
66.	Sept. 10 to Sept. 16..... ...	67·5	......	1,514,500	67	801,100
67.	Sept. 17 to Sept. 23.........	59	......	1,696,700	64	715,400
68.	Sept. 24 to Sept. 30.........	53	3·50	2,620,500	60	818,200 (partly computed)
69.	Oct. 1 to Oct. 7	57	0·86	2,134,100	60	1,178,000 (partly computed)
70.	Oct. 8 to Oct. 14	54·5	0·01	1,657,300	60	1,275,900
71.	Oct. 15 to Oct. 21	58	0·47	1,870,200	60	1,334,900
72.	Oct. 22 to Oct. 28	53	0·18	1,792,300	59·5	1,272,900
73.	Oct. 29 to Nov. 4............	49	0·02	1,738,700	59	1,172,700
74.	Nov. 5 to Nov. 11	43	0·05	1,556,800	57	915,900
75.	Nov. 12 to Nov. 18	39·5	0·23	1,488,400	55·5	651,700
76.	Nov. 19 to Nov. 25	36	0·04	1,492,100	53	716,100
77.	Nov. 26 to Dec. 2	39	0·10	1,575,000 (computed)	51·5	519,500
78.	Dec. 3 to Dec. 9	32·5	0·02	1,305,300	50	569,500
79.	Dec. 10 to Dec. 16	40	0·01	1,570,500	49	709,200
80.	Dec. 17 to Dec. 23	43	0·48	1,643,600	50	833,300
81.	Dec. 24 to Dec. 30	45	0·46	1,846,600	49	845,300
	1871. 1872.					
82.	Dec. 31 to January 6	44	0·81	2,069,200	49	963,400
83.	Jan. 7 to Jan. 13	40·5	0·57	2,380,400	49	1,027,500 (partly computed)

Sewage-Farm.

Diluted Sewage pumped or flowing by gravitation on to the Land, and of ing from the Drains.

last Report.]

Average temperature thereof.	Quantity of sewage, or diluted sewage, pumped on to tableland (six days per week where not otherwise stated).	Average temperature thereof.	Proportion of effluent water to sewage pumped.	Sewage only.		Effluent water.		
				Pumped.	Run on to bottom land by gravitation.	Pumped.	Run into river.	Run on to bottom land by gravitation.
° F.	galls.	° F.		galls.	galls.	galls.	galls.	galls.
59	1,791,400	63	·460	1,409,400	nil	348,100	476,600	nil
59	2,050,900	63	·437	1,760,000	nil	389,900	507,000	nil
59	1,983,100	63·5	·320	1,549,600	nil	313,800	320,800	nil
60	1,926,300	65	·348	1,351,800	110,700	601,900	68,300	nil
62	2,115,000	66	·308	1,620,900	88,000	474,200	178,100	nil
61	1,756,100	65·5	·351	1,560,400	nil	195,700	421,800	nil
61	1,481,500	66	·335	1,034,200	576,200	435,300	60,400	nil
60·5	1,705,700	66	·370	1,284,600	467,800	445,200	92,400	93,500
61	1,665,900	66	·481	1,209,900	304,600	508,900	238,400	53,800
60	1,872,000	63	·382	1,432,900	263,800	643,100	53,200	19,100
58	1,025,900 (5 days only)	58	·797	504,200	2,116,300	52,800	541,500	223,900
57	669,700 (4 days only)	59	1·759	871,100	1,263,000	114,800	838,200	225,000
55·5	2,003,800	58	·636	1,657,300	nil	312,300	963,600	nil
55	1,940,000 (7 days)	59	·688	1,804,500	65,700	318,000	990,900	26,000
54·5	2,220,200 (7 days)	58	·573	1,792,300	nil	267,200	1,005,700	nil
53	2,011,100 (7 days)	57	·583	1,688,500	50,200	252,200	916,300	4,200
51	1,794,100	56	·510	1,556,800	nil	207,800	708,100	nil
48	1,545,000	54	·422	1,408,400	80,000	150,000	494,900	6,800
46	1,221,400 (5 days only)	52	·586	893,800	598,300	110,300	544,700	61,100
44	nil	......	......	nil	1,575,000	nil	344,500	175,000
44	1,239,900	48	·419	1,257,500	47,800	168,500	364,200	36,800
44	1,608,500	47·5	·441	1,534,500	36,000	113,400	595,800	nil
44	1,947,300	48	·428	1,643,600	nil	251,200	582,100	nil
44	1,682,700 (7 days)	48	·502	1,496,600	350,000	242,600	551,400	51,300
44	1,898,500	47	·507	1,604,300	464,900	262,800	634,600	66,000
......	1,550,700	47	·663	1,418,100	962,300	56,100	818,900	152,500

TABLE I.

Number of weekly return.	Date (inclusive).	Average noonday temperature.	Rainfall during week.	Quantity of sewage delivered to the farm from the town.	Average temperature thereof.	Quantity of effluent water flowing out of the drains.
	1872.	° F.	in.	galls.	° F.	galls.
84.	Jan. 14 to Jan. 20	40	0·61	2,368,500	49	837,600 (partly computed)
85.	Jan. 21 to Jan. 27	44	0·94	2,341,900	48·5	989,200 (partly computed)
86.	Jan. 28 to Feb. 3............	48	0·03	2,341,600	49·5	628,000 (partly computed)
87.	Feb. 4 to Feb. 10............	50	0·21	2,229,800	51·5	725,900 (partly computed)
88.	Feb. 11 to Feb. 17	46·5	0·07	2,008,000	51·5	857,900 (partly computed)
89.	Feb. 18 to Feb. 24	49	0·23	1,907,600	52·5	1,107,000
90.	Feb. 25 to March 2	50	0·08	1,875,000	52	802,800 (partly computed)
91.	March 3 to March 9	54	0·21	1,992,100	55	821,100
92.	March 10 to March 16......	49	0·02	1,900,000 (computed)	52	697,000 (partly computed)
93.	March 17 to March 23......	42	0·55	2,113,800	53	726,200
94.	March 24 to March 30......	48	1·22	2,500,000 (computed)	50·5	700,000 (computed)
95.	March 31 to April 6	51	0·83	2,350,000 (partly computed)	52	700,000 (computed)
96.	April 7 to April 13.........	58·5	0·04	2,019,500 (partly computed)	54·5	687,400
97.	April 14 to April 20	52·5	0·01	2,029,500	54	1,013,900
98.	April 21 to April 27	56	0·48	2,041,700	55	1,429,600
99.	April 28 to May 4	60	0·07	1,878,200	56·5	1,773,200
100.	May 5 to May 11............	53	0·68	2,026,200	57·5	1,621,800
101.	May 12 to May 18	52	1·77	2,762,700	55·5	1,429,400
102.	May 19 to May 25	58	0·04	2,025,400	56	1,284,300
103.	May 26 to June 1............	64	0·10	1,990,000	58	1,121,100
104.	June 2 to June 8............	58	0·59	1,875,100	58	1,408,400
105.	June 9 to June 15	65·5	0·29	1,785,100	59	880,700
106.	June 16 to June 22.........	74	0·27	1,475,000	62·5	1,231,300
107.	June 23 to June 29.........	67	......	2,003,500	63	914,800
108.	June 30 to July 6	73	0·09	1,479,900	64	949,800
109.	July 7 to July 13............	72	1·08	1,618,300	65·5	1,242,900

...inued).

Average temperature thereof	Quantity of sewage, or diluted sewage, pumped on to tableland (six days per week where not otherwise stated).	Average temperature thereof.	Proportion of effluent water to sewage pumped.	Sewage only.		Effluent water.		
				Pumped.	Run on to bottom land by gravitation.	Pumped.	Run into river.	Run on to bottom land by gravitation.
° F.	galls.	° F.		galls.	galls.	galls.	galls.	galls.
44	1,115,100 (5 days only)	46	·751	1,052,400	1,316,100	nil	837,600	nil
......	452,900 (2 days only)	46·5	2·184	504,400	1,837,500	nil	100,000	889,200
45	1,353,500	49	·464	1,346,000	995,600	nil	472,700	155,300
......	1,596,000	50·5	·454	1,505,400	724,400	nil	675,900	50,000
......	1,930,000	50	·445	2,008,000	nil	161,100	696,800	nil
45	2,126,500	50·5	·521	1,725,600	182,000	172,500	915,100	19,400
45	23,000 (1 day only)	.....	......	nil	1,875,000	592,800	nil	210,000
47	1,790,900	53·5	·458	1,642,100	350,000	173,700	597,200	50,200
46	nil	......	......	nil	1,900,000	nil	447,000	250,000
46	1,990,100	51	·365	1,803,800	310,000	220,300	478,700	27,200
......	44,700 (1 day only)	......	......	95,000	2,405,000	10,500	450,000	239,500
......	119,700 (1 day only)	......	.. ..	nil	2,350,000	nil	450,000	250,000
48	793,900 (4 days only)	54	·866	1,029,500	990,000	71,300	495,000	121,100
49	2,258,700	53	·449	2,029,500	nil	229,200	784,700	nil
49	2,281,500	54	·627	2,041,700	nil	207,300	1,222,300	nil
50·5	2,247,000	56	·789	1,878,200	nil	328,900	1,444,300	nil
51	2,185,400	56	·742	2,026,200	nil	215,300	1,406,500	nil
51	2,778,200	54	·515	2,485,900	276,800	272,100	1,132,300	25,000
52	1,748,600	56	·734	1,553,700	471,700	159,000	1,055,300	70,000
53	2,052,400	59	·546	1,990,000	nil	198,300	922,800	nil
54	2,253,200	57·5	·625	1,875,100	nil	326,400	1,082,000	nil
54·5	1,789,200	59	·492	1,515,700	269,400	222,900	626,700	31,100
56	2,399,100	61·5	·513	1,475,000	nil	974,700	185,200	71,400
58	2,088,300	62	·438	1,911,100	92,400	175,900	738,900	nil
59	1,400,000 (5 days only)	63	·678	1,118,000	361,900	295,100	612,900	41,800
59	2,394,100	64	·519	1,441,700	176,600	752,900	473,000	17,000

TABLE II.—*Breton's*

Statement showing results of analyses for Nitrogen in Sewage as

Results given in

Analysis number.	Dates.	Sewage as pumped. Nitrogen. In solution. As ammonia.	Organic.	As nitrates and nitrites.	Total.	In suspension.	Total in solution and suspension.
	1871.						
7.	July 10 to July 15	......	......	......	4·33	1·15	5·48
8.	July 24 to July 29	......	......	......	3·80	0·45	4·25
9.	August 7 to August 12	2·93	1·64	......	4·57	0·87	5·44
10.	August 21 to August 26	2·58	0·65	......	3·23	0·99	4·22
11.	September 4 to September 9	2·70	0·53	......	3·23	2·53	5·76
12.	September 18 to September 23	1·84	1·41	......	3·25	1·10	4·35
13.	October 2 to October 7	2·12	0·50	......	2·62	2·95	5·57
14.	October 16 to October 21	2·43	1·06	......	3·49	1·50	4·99
15.	October 30 to November 4	1·66	2·15	......	3·81	2·47	6·28
16.	November 13 to November 18	2·98	2·28	......	5·26	1·46	6·72
	1872.						
17.	January 1 to January 8	2·17	1·24	......	3·41	2·64	6·05
18.	January 22 to January 27	3·15	1·27	......	4·42	2·20	6·62
19.	January 29 to February 3	2·51	0·67	......	3·18	3·36	6·54
20.	March 18 to March 23	4·54	0·88	......	5·42	1·14	6·56
21.	April 9 to April 13	3·426	0·30	......	3·72	2·67	6·39
22.	May 13 to May 18	1·96	1·50	......	3·12	0·91	4·03
23.	June 10 to June 15	1·88	0·87	......	2·75	1·27	4·02

Sewage-Farm.

pumped and Effluent Drainage-water from July 1871 to June 1872.

parts per 100,000.

Drains.	Effluent drainage-water. Nitrogen. In solution. As ammonia.	Organic.	As nitrates and nitrites.	Total.	In suspension.	Total in solution and suspension.
A	....	....	2·00	2·19		Average
B	....	....	0·84	1·29	......	1·12
C	....	....	0·49	0·87		
D	....	....	trace	0·13		
B	0·01	0·19	1·74	1·95		
C	0·026	0·31	1·12	1·45	......	1·27
D	0 004	0·18	0·24	0·42		
B	0·027	0·34	1·22	1·58		
C	0·083	0·18	0·63	0·88	......	1·39
D	0·007	0·17	1·53	1·71		
B	0·019	0·28	1·86	2·16		
C	0·100*	0·29	nil	0·37	......	1·17
D	0·013	0·24	0·73	0·97		
B	0·100	0·31	0·76	1·15		
C	0·020	0·17	1·20	1·39	......	1·27
D	0·009	0·15	1·12	1·28		
B	0·032	0·25	1·04	1·32		
C	0·049	0·21	0·47	0·72	......	0·95
D	0·019	0·20	0·60	0·82		
B	0·046	0·20	3·03	3·27		
C	0·012	0·83	1·72	2 56	......	2·67
D	0·011	0·90	1·27	2·18		
B	0·103	0·24	1·10	1·36		
C	0·109	0·23	0·53	0·85	......	0·95
D	0·013	0·11	0·52	0·64		
Average three drains	0·045	0·236	0·38	0·65	......	0·65
Average three drains	0·111	0·15	0·27	0·51	......	0·51
Average three drains	0·165	0·22	0·05	0·266	......	0·266
No samples taken.						
Average three drains	0·023	0·147	1·61	1·78	......	1·78
Average three drains	0·138	0·12	1·46	1·70	......	1·70
Average three drains	0·055	0·03	1·74	1·83	......	1·83
Average five drains	0·044	0·30	0·26	0·60	......	0·60
Average five drains	0·054	0·09	0·77	0·91	......	0·91

* Strong smell of sewage.

TABLE III.—*Breton's Sewage-Farm.*

Statement showing the Monthly Quantities of Sewage distributed and Nitrogen contained therein, and of Effluent Water discharged and Nitrogen contained therein, for the period from March 25, 1871, to March 24, 1872.

Dates (inclusive).	Sewage (or diluted sewage) pumped.			Effluent water.		
	Quantity.	Nitrogen per 100,000 tons.	Total Nitrogen.	Quantity.	Nitrogen per 100,000 tons.	Total Nitrogen.
1871.	tons.	tons.	tons.	tons.	tons.	tons.
March 25 to April 24 ...	24,059	6·48	1·5590	15,404	1·76	·2711
April 25 to May 24	37,154	5·21	1·9357	18,092	1·21	·2189
May 25 to June 24	39,017	4·03	1·5724	16,335	·76	·1241
June 25 to July 24	31,809	5·35	1·7018	16,319	1·33	·2170
July 25 to August 24 ...	39,862	4·63	1·8456	13,604	1·28	·1741
August 25 to Sept. 24 ...	37,424	4·78	1·7889	12,931	1·13	·1461
Sept. 25 to Oct. 24.........	37,684	5·30	1·9973	22,578	1·30	·2935
Oct. 25 to Nov. 24.........	34,985	6·50	2·2740	(partly computed) 18,194	0·58	·1055
Nov. 25 to Dec. 24	21,954	6·38	1·4007	12,649	0·39	·0493
Dec. 25 to Jan. 24 (1872)	28,231	6·35	1·7926	(partly computed) 18,444	0·56	·1033
1872. Jan. 25 to Feb. 24.........	31,168	6·58	2·0509	(partly computed) 16,732	1·78	·2978
Feb. 25 to March 24......	16,880	6·55	1·1056	14,254	1·70	·2423
	380,227	average 5·529	21·0245	195,536	average 1·147	2·2430

The proportion of nitrogen escaping in the effluent water to the total quantity applied is therefore ·1067, or about $\frac{1}{10}$.

The succeeding Tables, Nos. IV. to VI., show the relations between the amount and composition of the Sewage applied to the land during the twelve months under review (the amount given as applied to each plot being necessarily, at the best, only an approximation)—the amount of the various Crops, as estimated from the weight of average samples, and their composition as far as it could be ascertained from the most reliable data, viz. tables furnished by Messrs. Lawes and Gilbert, and those published in the Second Report of the Sewage of Towns' Commission—and the amount and composition of the effluent water.

Tables V. and VI. also show the amount of nitrogen unaccounted for, which either remains in the soil or has partly drained away into deep subsoil-waters.

TABLE IV.—*Breton's*

Statement showing Sewage applied and Crops grown

Description.					
I.	II.	III.	IV.	V.	VI.
Plot.	No. of beds (inclusive).	Contents.	Crop.	Date when sown or planted.	Date when cut or gathered.
		acres.			
A	1 to 29	9·8	Cabbages and greens	Oct. 1870	May to Aug. 1871
"	" "	...	Cauliflower and broccoli-plants.	April 1871	July 1871 ......
"	1 to 18	5·7	Savoys	Aug. "	Feb. and March 1872
"	19 " 20	0·8	Cabbage-plants	" "	Oct. 1871 ....
"	21 " 26	2·3	Cabbages	June "	" " ....
"	27 " 29	1·0	Cauliflowers and vegetable marrows	" "	Aug. to Oct. 1871 ..
"	1 " 29	9·8	Fallow	....	....
Total A	All.	9·8	....	....	....
B	1 to 20	9·5	Italian rye-grass	part April 1870 part Sept. " part March 1871	April to Oct. 1871...
"	21 " 26	2 6	Potatoes	March 1871	Oct. 1871 ....
"	9 " 26	8·25	Cabbages	Oct. "	....
"	1 " 8	3·87	Italian rye-grass	part Sept. 1870 part Mar. 1871	....
Total B	....	12·1	....	....	....
C	All.	2·0	Cabbages	June 1871...........	Oct. 1871 ....
"	"	2·0	Fallow	....	....
Total C	All.	2·0	....	....	....
D	All.	6·9	Potatoes	April 1871	July to Sept. 1871..
"	"	6·9	Hardy greens	Sept. "	Dec. to March 1872
Total D	All.	6·9	....	....	....

* The figures in columns marked thus (*) are to be considered

Sewage-Farm.

from March 25, 1871, to March 24, 1872.

Approximate estimate of sewage applied.			Produce.			
VII.	VIII.	IX.	X.	XI.	XII.	Remarks.
No. of dressings.	Total. *	Per acre. *	Total.	Per acre.	Sewage applied per ton of produce. *	
	tons.	tons.	tons.	tons.	tons.	
4	6,433	656	354·66 / 3·36	36·53	17·9	One quarter only of this crop was sold. It received four dressings of sewage previous to March 1871, being about the same quantity as here stated. The small plants computed to weigh ½ oz. each.
7	13,720	2,407	93·48	16·39	146·7	This crop, with the exception of 1·7 ton, was consumed by cattle on the farm.
1	356	444	15·48	19·35	23·0	Plants computed to weigh ½ oz. each.
6	4,212	1,831	52·21	22·70	80·7	
7	1,942	1,942	6·53	6·53	297·4	
...	9,563	.. ...	.. ...	......	.. ...	This sewage was applied to the fallow, Dec. 1871 to Feb. 1872.
...	36,226	3,697	525·72	53·60	68·9	
...	39,012	4,106	451·20	47·5	86·4	This grass received a large quantity of sewage (nearly as much as is here stated) previous to March 25th, 1871.
2	1,033	397	5·15	1·98	200·0	
2	8,577	1,050	......	......	......	This crop received no more sewage, and was cropped May and June 1872.
1	1,108	286	......	......	......	There was no cutting of this grass previous to March 25th, 1872.
...	49,730	4,110	456·35	37·7	108·9	There was a standing crop of cabbage at the end of the year.
...	5,062	2,531	68·31	34·15	74·1	
...	20,328	10,164	...	...	.. ...	Applied Nov. 1871 to March 5th, 1872.
...	25,390	12,695	68·31	34·15	371·7	It will be seen that the greater part of this sewage went on the fallow. Only cultivated four months.
4	7,703	1,116	23·40	3·40	329·2	
4	11,502	1,667	61·24	8·88	187·8	
...	19,205	2,783	84·64	12·27	226·9	
	*	*			*	

only as approximations, for reasons stated in the Report.

TABLE IV.

Description.					
I.	II.	III.	IV.	V.	VI.
Plot.	No. of beds (inclusive).	Contents.	Crop.	Date when sown or planted.	Date when cut or gathered.
		acres.			
E	1 to 6	1·7	Onions	April 1871	Oct. 1871 ....
"	7	0·3	Savoys	Sept. "	March 1872 ....
"	8 to 11	1·1	{ Hardy greens ...... Savoy-plants.........	} Sept. "	" " ....
"	12 and 13	0·5	{ Cabbages .... Cabbage-plants ...	} July "	Oct. to Dec. 1871 ...
"	14 to 22	2·2	Strawberries...........	Autumn 1870	July 1871 ....
"	1 " 13	3·6	Fallow	....	....
Total E	....	5·8	....	....	.. ..
F	1 to 3	0·64	Potatoes	March 1871	Sept. 1871............
"	4 " 14	2·33	Cabbages	Oct. 1870	May to Aug. 1871 ..
"	15 " 18	0·85	Carrots...................	March 1871	Aug. to Oct. " ..
"	1 " 3	0·64	Cabbages	Sept. "	March 1872 ....
"	4 " 14	2·33	Hardy greens and cauliflowers.	July and Aug. 1871	Sept. 1871 to Feb. 1872.
"	....	...	Fallow	....	....
Total F	....	3·82	....	....	....

* The figures in columns marked thus (*) are to be considered

(*continued*).

Approximate estimate of sewage applied.			Produce.			Remarks.
VII.	VIII.	IX.	X.	XI.	XII.	
No. of dress-ings.	Total. *	Per acre. *	Total.	Per acre.	Sewage applied per ton of produce. *	
	tons.	tons.	tons.	tons.	tons.	
9	5,690	3347	26·83	15·78	212·1	
9	985	3283	4·53	15·10	217·4	
10	4,110	3736	{ 24·29 { 4·24	} 25·94	144·0	About one tenth only of the greens was bunched for market. The remaining nine tenths were consumed by cattle on the farm.
6	1,643	3286	{ 11·25 { 5·20	} 32·90	100·0	One half only of the cabbages was sold; the remainder ploughed in.
2	742	337	......	......	......	The strawberries received 279 tons of sewage previous to March 1871. The plants remain in the ground. The yield was thirty punnets only.
...	6,670	1853	......	......	......	Applied Dec. 1871 to March 1872.
...	19,840	3421	76·34	13·16	259·9	
3	397	620	1·71	2·67	232·0	
8	3,304	1418	98·64	42·33	33·5	Three quarters of this crop was ploughed in, there being no sale for it.
4 to 5	1,318	1551	10·45	12·29	126·1	
2	559	873	6·75	10·54	82·8	One half of this crop was ploughed in, there being no sale for it.
2 to 4	2,532	1087	24·20	10·39	64·6	
...	2,218	......	......	...	......	Applied Nov. 1871 to Feb. 1872.
...	10,328 *	2704 *	141·75	37·11	72·8 *	

only as approximations, for reasons stated in the Report.

TABLE IV.

Description.					
I.	II.	III.	IV.	V.	VI.
Plot.	No. of beds (inclusive).	Contents.	Crop.	Date when sown or planted.	Date when cut or gathered.
		acres.			
G	2 and 3	0·47	Cabbages	Oct. 1870	May to July 1871 ..
,,	17	0·23	Parsley..................	April 1871	....
,,	18	0·23	Brussels sprouts	,, ,, ...	....
,,	1	0·23	Beans	March 1871	Sept. 1871...........
,,	10 and 11	0·47	Onions	,, ,, ...	,, ,, ...
,,	4 to 9	1·41	Carrots	,, ,, ...	Aug. ,, ...
,,	12 to 13	0·47	Clover	May ,, ...	....
,,	14	0·24	Cauliflowers...........	,, ,, ...	July to Sept. 1871 .
,,	15 and 16	0·47	Lettuce..................	,, ,, ...	Aug. 1871 ....
,,	19	0·24	Cauliflowers...........	July ,, ...	Oct. ,, ...
,,	20 to 22	0·71	Spinach	April and May 1871	May and June 1871
,,	3, 17, 20, 21 and 22	1·18	Cauliflowers	July 1871	Aug. to Oct. 1871..
,,	1 and 2	0·47	Hardy greens	Sept. ,, ...	March 1872 ....
,,	4 to 9	1·41	Onions	Aug. ,, ...	.. ..
,,	10 and 11	0·47	Cabbages	Sept. ,, ...	March 1872 ....
,,	12	0·23	Savoys	,, ,, ...	,, ,, ...
,,	13 and 14	0·47	Hardy greens	Oct. ,, ...	....
,,	15 ,, 16	0·47	Spinach.................	Aug. ,, ...	Jan. 1872 ....
,,	3 & 17 to 20	1·64	Fallow	....	....
Total G	....	5·17	....	....	....
H	1 to 24	6·4	Onions	March 1871	July to Oct. 1871...
,,	1 ,, 24	6·4	Cabbages	Sept. ,, ...	....
Total H	....	6·4	....	....	....
I	1 to 3	1·11	Potatoes	March 1871	Sept. 1871...........
,,	4 ,, 9	2·27	Cabbage	Oct. 1870	May to Aug. 1871 ..
,,	10 ,, 18	3·29	Carrots	March 1871	Sept. 1871...........
,,	1 ,, 3	1·11	Hardy greens	Sept. ,, ...	....
,,	4 ,, 9	2·27	Ditto and cauliflowers	July and Aug. 1871	Sept. 1871 to Feb. 1872.
,,	10 ,, 18	3·29	Cabbages	Sept. and Oct. ,,	....
Total I	....	6·67	....	....	....

* The figures in columns marked thus (*) are to be considered

(*continued*).

Approximate estimate of sewage applied.			Produce.			Remarks.
VII.	VIII.	IX.	X.	XI.	XII.	
No. of dressings.	Total. *	Per acre. *	Total.	Per acre.	Sewage applied per ton of produce. *	
	tons.	tons.	tons.	tons.	tons.	
5	759	1615	4·29	9·13	176·9	
1	109	474	...	...	......	This crop was ploughed in. Quantity not ascertained.
2	163	709	6·00	26·10	27·2	Part of the plants was transplanted; the remainder was pulled for cattle.
3	211	917	0·27	1·19	781·0	
5	928	1974	10·65	22·67	87·1	
...	4,050	2872	6·22	4·41	651·1	
1	162	345	4·23	9·00	38·3	This crop was cut only once, and then ploughed in.
6	526	2192	0·56	2·34	939·3	
5	983	2092	0·30	0·64	3277·0	Only one quarter of this crop was sold; the remainder consumed by cattle.
5	443	1845	0·56	2·34	791·0	
5	1,263	1779	1·23	1·73	1318·0	One third of this crop was sold; the remainder consumed by cattle on farm.
4	2,477	2099	2·24	1·90	1104·0	
5	926	1970	2·13	4·53	434·1	
1	802	569	...	...	.....	This crop remained in the ground till May 1872.
5	1,126	2396	4·30	9·17	261·6	
6	590	2565	3·69	16·05	159·9	
6	1,109	2360	...	...	......	This crop received no more sewage, and was gathered May 1872.
1	247	525	1·02	1·60	329·3	
1	5,198	3170	......	.....	....	Applied from October to February.
...	22,072	4269	47·69	9·17	462·8	
6 to 7	14,015	2190	136·47	21·32	102·7	
about 2	6,387	998	......	......	......	This crop received no more sewage, and commenced cutting April 1872.
...	20,402	3188	136·47	21·32	149·4	Standing crop at the end of the year.
2	708	638	3·41	3·07	207·6	
10	5,724	2521	110·10	48·50	52·0	Only one quarter of this crop was sold, the remainder ploughed in.
8	7,044	2141	47·03	14·30	149·8	
4	1,758	1584	...	....	......	This crop received no more sewage, and was gathered in the summer of 1872.
7	4,612	2032	27·31	12·04	168·9	
2	2,691	818	......	......	......	This crop received no more sewage, and was gathered April 1872.
...	22,537 *	3379 *	187·85	28·16	120·0 *	Standing crop at the end of the year.

only as approximations, for reasons stated in the Report.

TABLE IV.

Description.					
I.	II.	III.	IV.	V.	VI.
Plot.	No. of beds (inclusive.)	Contents.	Crop.	Date when sown or planted.	Date when cut or gathered.
		acres.			
K	All.	4·40	Cabbages	Nov. 1870............	June to Aug. 1871 ..
„	„	3·66	Hardy greens	Sept. 1871	March 1872 ....
		average			
Total K	....	4·03	....	....	....
M	All.	3·56	Onions	March 1871	Aug. to Oct. 1871...
„	„	3·17	Cabbages	Oct. „	....
		average			
Total M	....	3·36	....	....	....
N	1 to 4 and 9 to 16	3·12	Cabbage	Oct. 1870	May to July 1871..
„	1 to 6 and 9 to 16	2·63	Hardy greens and cauliflowers.	May to July 1871 ..	Nov. and Dec. 1871
„	7 and 8	0·52	Broccoli	July 1871	....
„	....	...	Fallow	....	....
Total N	....	4·15	....	....	....
O	All.	5·92	Italian rye-grass	Sept. 1870............	April to July 1871..
„	„	5·92	Cabbages	July 1871	Feb. 1872 ....
Total O	....	5·92	....	....	....
P	Part.	1·45	Potatoes	April 1871	Sept. 1871............
„	„	1·6	Beans (scarlet).........	May „	Aug. to Oct. 1871...
„	„	0·45	Savoys	June 1871............	Oct. 1871 ....
„	All.	3·5	Fallow	....	....
Total P	....	3·5	....	....	....

* The figures in columns marked thus (*) are to be considered

(*continued*).

Approximate estimate of sewage applied.			Produce.			
VII.	VIII.	IX.	X.	XI.	XII.	Remarks.
No. of dressings.	Total. *	Per acre. *	Total.	Per acre.	Sewage applied per ton of produce. *	
	tons.	tons.	tons.	tons.	tons.	
10	10,300	2341	192·37	43·72	53·2	Only one quarter of this crop was sold; the remainder ploughed in. It received 2636 tons of sewage between Nov. 1870 and March 1871.
6	8,876	2425	45·00	12·30	197·2	Only one tenth of this crop was sold; the remainder ploughed in.
...	19,176	4758	237·37	58·90	80 8	The acreage of this plot has been altered.
5 to 6	7,559	2123	57·18	16·05	132·2	
3	4,394	1386	......	......	......	This crop received more sewage, and was gathered May and June 1872.
...	11,953	3557	57·18	17·01	209·0	Standing crop at the end of the year The acreage of this plot has been altered.
about 8	6,798	2179	166·81	53·46	40·7	One quarter only of this crop was sold; the remainder ploughed in. The crop received 3718 tons of sewage previous to March 25, 1871.
about 6	9,683	2738	55·53	15·30	174·3	
...	2,194	4219	......	......	......	This crop received no more sewage, and was gathered April 1872.
...	13.543	......	......	.	.. ..	Applied Dec. 1871 to March 1872.
...	32,218	7763	222·34	53·57	144·9	
10	9,936	1678	117·18	19·80	84 8	This crop received nearly 10,000 tons of sewage previous to March 25, 1871.
5	9,599	1621	141·03	23·82	68·1	Only half this crop was sold: the remainder consumed by cattle on the farm.
...	19,535	3299	258·21	43·62	75·6	
4	1,235	852	1·875	1 29	660·4	
8	4,096	2560	1·45	0·90	2824·9	
5	1,074	2387	20 34	45·21	52·8	One third of this crop was sold; two thirds consumed by cattle on the farm.
...	9,249	2643	......	......	......	Applied Oct. 1871 to Feb. 1872.
...	15,654 *	4473 *	23·665	6·76	661·5 *	

only as approximations, for reasons stated in the Report.

TABLE IV.

Desciption.					
I.	II.	III.	IV.	V.	VI.
Plot.	No. of beds (inclusive).	Contents.	Crop.	Date when sown or planted.	Date when cut or gathered.
		acres.			
Q	Part.	0·43	Mangold	April 1871	Nov. 1871 ....
"	"	0·21	Beet-root	May "	Oct. to Nov. 1871...
"	"	0·75	Hardy greens	Aug. "	Dec. 1871 .. ..
"	"	0·21	Carrots.....	May "	Nov. " ....
Total Q	....	1·60	....	....	....
R	1 to 7	0·90	Oats	April 1871	Aug. 1871 ....
"	8 " 20	1·62	Parsnips	" "	Dec. " .. ..
"	1 " 7	·90	Hardy greens	Sept. "	Dec. 1871 and Jan. 1872.
Total R	....	2·52	....	....	....
S	Part.	0·33	Cabbages	July 1871	Oct. 1871 ....
T	All.	0·34	Potatoes	April 1871	Sept. 1871..... ......
"	"	0·34	Cabbages	Sept. "	March 1872 .. ...
Total T	....	0·34	....	....	....
U	Part.	2·03	Hardy green plants..	April 1871	Aug. and Sept 1871
"	"	0·50	Peas	July "	Sept. 1871...... .....
"	All.	2·53	Sprouting broccoli ...	Oct. "	....
Total U	....	2 53	....	....	....
V	Part.	1·36	Mangold	May 1871	Nov. 1871 . . . ..
"	"	0·36	Cauliflowers	June "	Aug. 1871 to Jan. 1872.
"	"	0·50	White broccoli .. .	" "	....
"	"	0·26	Cabbages	May "	Nov. and Dec. 1871
"	"	2·00	Cabbages	Oct. "	....
"	....	...	Fallow	.. ..	....
Total V	....	4·48	....	....	....
W	Part.	1·0	Hardy green plants..	April 1871	Aug. and Sept. 1871
"	All.	3·0	Fallow	....	....
Total W	....	3·0	....	....	....
X	All.	3·86	Savoys	Aug. 1871............	Jan. to March 1872
Y	All.	5 6	Hay	Permanent grass ...	Permanent grass ...

* The figures in columns marked thus (*) are to be considered

(*continued*).

Approximate estimate of sewage applied.			Produce.			Remarks.
VII.	VIII.	IX.	X.	XI.	XII.	
No. of dressings.	Total. *	Per acre. *	Total.	Per acre.	Sewage applied per ton of produce. *	
	tons.	tons.	tons.	tons.	tons.	
7	1,595	3709	7·45	17·33	214·1	
5	1,207	5748	2·10	10·00	574·8	
5	1,871	2495	3·03	4·04	616·9	
3	881	4195	0·75	3·57	1174·7	
...	5,554	3471	13·33	8 33	416·7	
1	450	500	†3·00	3·33	150·0	†This weight includes straw 2·25 tons.
4	2,328	1437	12·50	7·71	186 2	
3	2,066	2296	3·74	4·25	497·2	
...	4,844	1922	19·24	7·63	251·7	
1	70	211	2 65	8·05	26 4	
nil	nil	.. ...	2·10	6·18	......	These crops received no sewage.
,,	,,	.. ...	0·96	2·82	.. ...	
...	nil	.... .	3 06	9 00	.. ...	No sewage applied.
nil	nil	.. .	17·86	8 80	......	These plants received no sewage, and were replanted on the farm.
3	655	1310	·0·87	1 74	752 9	
17	5,797	2292	......	...	......	This crop received no more sewage, and was gathered April 1872, yielding 13·40 tons.
...	6,452	2550	18 73	7·40	344·4	
4	1,873	1429	22 80	16·76	82·1	
8	1,812	5033	0 90	2·50	2013·5	
8	2,126	4252	......	......	......	This crop received no more sewage, and was gathered April 1872, yielding 2·91 tons.
7	832	3200	3·73	14·37	222·7	
1	2,053	1027	... ..	.. ...	... .	This crop commenced cutting May 1872.
2	1,850	... ..	......	......	......	Applied Jan. 1872.
...	10,546	2354	27·43	6 12	384·4	
3	552	552	8·92	8·92	61·9	These plants transplanted to other parts of the farm.
...	8,345	2782				
...	8,897	2966	8·92	2·98	997·5	
7	2,773	718	75 9	19 66	36·5	Only one tenth of this crop was sold; the remainder carted to cattle.
abt. 12	16,825 *	3004 *	21·3	3·8	789·9 *	The grass remains.

only as approximations, for reasons stated in the Report.

TABLE V.—*Breton's*

Summary for the Year ending March 24, 1872, showing the Nitrogen applied

Description.			Produce.		Approximate estimate of sewage applied.		
Plot.	Contents.	Crop.	Total.	Per acre.	Total. *	Per acre. *	Per ton of produce. *
	acres.		tons.	tons.	tons.	tons.	tons.
A	9·80	Cabbage, cauliflowers, and savoys	525·72	53·64	36,226	3,697	69
B	12·10	Italian rye-grass and potatoes	456·35	37·71	49,730	4,110	109
C	2·00	Cabbage	68·31	34·15	25,390	12,695	372
D	6·90	Potatoes and hardy greens	84·64	12·27	19,205	2,783	227
E	5·80	Onions, savoys, hardy greens, cabbage, and strawberries	76·34	13·16	19,840	3,421	260
F	3·82	Potatoes, carrots, cabbage, and hardy greens	141·75	37·11	10,328	2,704	73
G	5·17	Cabbage, brussels sprouts, beans, onions, carrots, clover, cauliflowers, lettuce, spinach, and hardy greens	47·69	9·23	22,072	4,269	463
H	6·40	Onions	136 47	21·32	20,402	3,188	149
I	6·67	Potatoes, cabbage, carrots, hardy greens, and cauliflowers	187·85	28·16	22,537	3,379	120
K	4·03	Cabbage and hardy greens	237·37	58 90	19,176	4,758	81
M	3·36	Onions	57·18	17·01	11,953	3,557	209
N	4·15	Cabbage, hardy greens, cauliflowers, and broccoli	222·34	53·57	32,218	7,763	145
O	5·92	Italian rye-grass and cabbage	258·21	43·62	19,535	3,299	76
P	3·50	Potatoes, scarlet beans, and savoys	23·665	6·76	15,654	4,473	662
Q	1·60	Mangold, beet-root, hardy greens, and carrots	13·33	8·33	5,554	3,471	417
R	2·52	Oats, parsnips, and hardy greens	19·24	7·63	4,844	1,922	252
S	·33	Cabbage	2·65	8·05	70	211	26
T	·34	Potatoes and cabbage	3·06	9·00	nil	nil	nil
U	2·53	Hardy green plants and peas	18·73	7·40	6,452	2,550	344
V	4·48	Mangold, cauliflowers, and cabbage	27·43	6·12	10,546	2,354	384
W	3·00	Hardy green plants	8·92	2·98	8,897	2,966	997
X	3·86	Savoys	75·90	19·66	2,773	718	37
Y	5·60	Hay (equal to four and a half times this quantity when green)	21·30	3·80	16,825	3,004	790
	103·88		2714·445	26·13	380,227	3,660	140

* The figures in columns marked thus (*) are to be considered only as approximations

ewage-Farm.

o the Land during that period, and its relation to the Produce of the Farm.

Approximate estimate of nitrogen.															
Quantity applied.			Quantity escaping in effluent water.	Difference (in soil, crops, &c.).			Calculated to be in crops.			Not accounted for (in soil, and drained away).			Per cent.		
* Total.	* Per acre.	* Per ton of produce.	*	* Total.	* Per acre.	* Per ton of produce.	Total.	Per acre.	Per ton of produce.	* Total.	* Per acre.	* Per ton of produce.	* In crop.	* In effluent water.	* Not accounted for (in soil).
lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.			
4,486	458	8·5	479	4,007	409	7·6	2,944	300	5·6	1,063	108	2·0	66	11	23
6,159	509	13·5	657	5,502	455	12·1	5,487	453	12·0	15	1	...	89	11	...
3,145	1572	46·1	335	2,810	1405	41·1	383	192	5·6	2,427	1213	35·5	12	11	77
2,379	345	28·2	254	2,125	308	25·1	474	69	5·6	1,651	239	19·5	20	11	69
2,457	424	32·2	262	2,195	378	28·8	410	71	5·4	1,785	308	23·4	17	11	72
1,279	335	9·0	136	1,143	299	8·0	782	205	5·5	361	95	2·5	61	11	28
2,734	529	57·4	292	2,442	472	51·2	294	57	6·2	2,148	416	45·0	11	11	78
2,527	395	18·6	270	2,257	353	16·5	672	105	4·9	1,585	248	11·6	26	11	63
2,792	419	14·9	298	2,494	374	13·3	999	150	5·3	1,495	224	8·0	36	11	53
2,375	590	10·0	253	2,122	526	8·9	1,330	331	5·6	792	196	3·3	56	11	33
1,480	440	25·9	158	1,322	394	23·1	282	84	4·9	1,040	310	18·2	19	11	70
3,990	961	17·9	426	3,564	859	16·0	1,245	300	5·6	2,319	559	10·4	31	11	58
2,420	409	9·4	258	2,162	365	8·4	2,206	373	8·5	...	..	...	91	11	...
1,939	554	81·9	207	1,732	495	73·2	157	45	6·6	1,575	450	66·6	8	11	81
689	431	51·7	73	616	385	46·2	74	46	5·6	542	339	40·7	11	11	78
600	238	31·2	64	536	213	27·9	147	58	7·7	389	154	20·2	24	11	65
9	27	3·5	1	8	24	3·0	15	45	5·6	...	...	...	167	11	...
...	...	..	.	...	.	..	17	50	5·6	...	...	...	...	...	...
800	316	42·7	85	715	282	38·2	166	65	8·9	549	217	29·3	21	11	68
1,306	291	47·5	139	1,167	260	42·6	154	34	5·6	1,013	226	37·0	11	11	78
1,102	367	123·5	118	984	328	110·3	50	17	5·6	934	311	104·7	4	11	85
343	89	4·5	37	306	80	4·0	425	110	5·6	...	...	...	124	11	...
2,084	372	97·8	222	1,862	332	87·6	954	170	44·8	908	162	42·6	46	11	43
47,095	453	17·35	5024	42,071	405	15·50	19,667	189	7·2	22,404	216	8·3	42	11	47

(for reasons stated in the Report), with the exception of the grand totals.

TABLE VI.—*Breton's*

Summary of Crops gathered during the period from March 25, 1871, to
Sewage applied

[N.B.—The Sewage here stated is only that applied during the above period. In

Crop.	Total acreage of each description of crop.	Produce of each crop.		Sewage ap- the
		Total.	Per acre.	Total. *
	acres.	tons.	tons.	tons.
Italian rye-grass	15·42	568·38	36·97	50,056
Hay (meadow)	5·60	21·30	3·80	16,825
Clover	·47	4·23	9·00	162
Cabbage	59·06	1242·10	21·03	80,879
Hardy greens	18·39	166·21	9·04	32,770
Savoys	10·54	202·18	19·18	19,142
Brussels sprouts	·23	6·00	26·09	163
Broccoli (crop in ground at end of year)	3·55	...	...	10,117
Spinach	1·18	2·25	1·91	1,510
Lettuce	·47	·30	·64	983
Cauliflowers	2·02	4·26	2·10	5,258
Parsley (crop ploughed in. Quantity not ascertained ...	·23	...	...	109
Beans	1·83	1·72	·94	4,307
Peas	·50	·87	1·74	655
Carrots	5·76	64·45	11·19	13,293
Parsnips	1·62	12·50	7·71	2,328
Beet-root	·21	2·10	10·00	1,207
Mangold	1·79	30·25	16·90	3,468
Onions	13·54	231·13	17·07	28,994
Potatoes	13·04	37·645	2·88	11,076
Oats	·90	3·00	3·33	450
Strawberries (yield of strawberries very small, quantity not stated)	2·20	...	...	742
Mixed crops—cauliflowers and vegetable marrows	1·00	6·53	6·53	1,942
Hardy greens and cauliflowers ...	8·23	107·04	13·01	16,827
Fallow land	...	...	...	76,964
Total	...	2714·445	...	380,227

* The figures in columns marked thus (*) are to be considered only as

Sewage-Farm.

March 24, 1872, showing the quantity of each kind of Produce and the thereto.

some cases, therefore, it does not represent the total quantity applied to the Crops.]

plied to crops. Per acre. *	Sewage applied per ton of produce. *	Nitrogen. Quantity applied in sewage. *	Quantity escaping in effluent water. *	Quantity estimated in crops. Per cent.	Total.	Not accounted for (in soil, &c.). *
tons.	tons.	lbs.	lbs.		lbs.	lbs.
3246	81·1	6,200	661	0·54	6,875	...
3004	789·9	2,084	222	2·00	954	908
345	38·3	20	2	0·65	62	...
1369	65·1	10,017	1069	0·25	6,955	1,993
1782	197·2	4,059	433	0·25	930	2,696
1816	964·2	2,371	253	0·25	1,132	986
709	27·2	20	2	0·25	34	...
2850	...	1,253	134	...	...	1,119
1280	671·1	187	20	0·25	12	155
2092	3277·0	122	13	0·25	2	107
2603	1234·2	652	69	0·25	24	559
474	...	13	1	...	...	12
2353	2504·1	533	57	1·00	39	437
1310	752·9	81	9	3·40	66	6
2308	206·2	1,646	176	0·20	289	1,181
1437	186·2	288	31	0·22	62	195
5748	574·8	149	16	0·25	12	121
1937	114·5	431	46	0·25	169	216
2141	125·4	3,591	383	0·22	1,139	2,069
849	294·2	1,372	346	0·25	211	1,015
500	150·0	57	6	{ Oats 2·00, straw 0·60 }	64	...
337	...	92	10	...	...	82
1942	297·4	241	26	0·25	36	179
2045	157·2	2,084	222	0·25	600	1,262
...	...	9,532	1017	...	...	8,515
...	140·1	47,095	5024	...	19,667	22,404
	Per cent.	100	1067	...	41·76	47·57

approximations (for reasons stated in the Report), with the exception of the grand totals.

Interim Report of the Committee appointed for the purpose of making experiments on instruments for Measuring the Speed of Ships and Currents by means of the difference of height of two columns of liquid, —the Committee consisting of Prof. W. J. Macquorn Rankine, C. W. Merrifield, F.R.S., Mr. F. J. Bramwell, *and* Mr. Alfred E. Fletcher (Secretary).

Your Committee have to report that, owing to the business-engagements of the Members, it has been found impossible to hold a meeting at a sufficiently early date to enable a systematic plan of operations to be agreed to and acted upon, and also that a proposed experimental trip in a yacht has been unavoidably postponed. No expense has been incurred, and no part of the grant of £30 has been drawn.

Your Committee recommend that they should be reappointed, and that the sum of £30 should again be placed at their disposal.

Report on the Rainfall of the British Isles, by a Committee, consisting of Charles Brooke, *F.R.S.* (*Chairman*), J. F. Bateman, *C.E.*, *F.R.S.*, J. Glaisher, *F.R.S.*, R. W. Mylne, *C.E.*, *F.R.S.*, Prof. J. Phillips, *F.R.S.*, T. Hawksley, *C.E.*, Prof. J. C. Adams, *F.R.S.*, Prof. J. J. Sylvester, *F.R.S.*, C. Tomlinson, *F.R.S.*, R. Field, *C.E.*, Dr. Pole, *C.E.*, *F.R.S.*, Prof. D. T. Ansted, *F.R.S.*, A. Buchan, *F.R.S.E.*, *and* G. J. Symons, *Secretary.*

Your Committee have the pleasure of reporting that every branch of rainfall work continues in efficient working order, and that, notwithstanding the very limited funds at our disposal and the long illness of our Secretary during the winter, all arrears have been overtaken, and, owing to the completeness of the organization, no hitch or interruption occurred.

At the Meeting of the British Association in Edinburgh, very strong representations were made to your Committee respecting the desirability of establishing additional rain-gauge stations in different parts of the Highlands; and as your Committee had long been aware of the necessity which existed for these stations, and, moreover, as somewhat larger funds than usual were at their disposal, they resolved on taking every means in their power to secure the efficient establishment of these stations. In addition to ordinary correspondence, our Secretary took two special steps to secure the most promising possible distribution of the new gauges. In the first place he wrote to Mr. Buchan, the Secretary to the Scottish Meteorological Society, acquainting him with the assent of the Committee, and requesting him to state what number of gauges he could provide good observers for. On receipt of his reply ten gauges were sent to him, which he was kind enough to distribute as follows:—

1. Springfield, Tain, Ross.
2. Kilmalcolm, Port Glasgow.
3. Arrochar, Loch Long.
4. Strahane, Brodick, Arran.
5. Strathfillan, Perthshire.
6. Sannox, Arran.
7. Kilchoman, Islay.
8. Port Charlotte, Islay.
9. Port Ellen, Islay.
10. Glenbarn Abbey, Mull of Cantire.

The other step was to send the following letter to the Secretary of the Highland Railway Company, whose line, as is probably generally known, traverses much of the most thinly inhabited part of Scotland:—

"62 Camden Square,
December 7th, 1871.

"BRITISH RAINFALL.

"DEAR SIR,—At the Meeting of the British Association held at Edinburgh last August, it was resolved that steps be taken to obtain observations of the fall of rain in those parts of Scotland in which they have not hitherto been made; a grant of money was voted for the construction of the instruments, and I was directed to take such steps as might seem best calculated to secure regular and trustworthy observations. As an indication that this application is for no mere crotchet, I may mention that the Board of Northern Lighthouses are already assisting all round the coast, and the Scottish Meteorological Society, the Marquis of Breadalbane, and others inland. After all our efforts, however, the route traversed by your line is very poorly supplied with observers; and I have therefore to ask whether you would cooperate in the matter by instructing certain of your station-masters to make the necessary observations and forward the results monthly. The gauges are similar to (but smaller than) those used by the station-masters on the Manchester, Sheffield, and Lincolnshire Railway; they are extremely simple, and the observations (which may be made any time between 8.30 and 9.30 A.M.) only occupy about two minutes: I should, of course, provide printed instructions and blank forms. The preliminary arrangements to ascertain exactly where additional observations are required have taken so long that there is now necessity for somewhat prompt action to secure that the instruments shall all be at their destination a few days before the end of the year. I shall therefore be glad of a prompt reply, especially as, *after* receiving it, either I or my colleague Mr. Buchan, of the Scottish Meteorological Society, will have to send communications to the '*Scotsman*' and other papers. I have only to add that if the Dingwall and Skye line is *not* under your control, I should be much obliged by a line or telegram stating to whom I should apply, unless, indeed, you could submit the tenour of my views to the authorities of that line, which would be the most rapid course. I enclose sketch of the gauge and instructions, which can be further simplified for the special purpose, and have only to add that, should any further explanation be required, I shall most cheerfully supply it.

"Yours very truly,
"G. J. SYMONS."

"*A. Dougall, Esq., Inverness.*"

To this letter the following reply was received:—

"Highland Railway Company, Inverness,
12th December, 1871.

"BRITISH RAINFALL.

"DEAR SIR,—I have your favour of the 7th instant on the above subject, and beg in reply to state that the Directors of this Company will be happy to cooperate in the matter by instructing several of their station-masters to make the necessary observations and to forward the results monthly. This will apply to the Dingwall and Skye line also.

"I am, yours faithfully,
"A. DOUGALL."

The result of subsequent correspondence was the establishment of a chain of stations over the entire system of the Highland and Dingwall and Skye railways. Fifty gauges, with pegs for fixing, instructions, and blank observation forms were sent to Inverness, and distributed and erected by the officials of the Company at various selected stations, with the exception of a few which are retained in store until the northern extension of the line will enable them to be placed in Sutherland and Caithness. It only remains to add that the station-agents, with scarcely an exception, understand their work and do it punctually and well. Another district in which additional stations are urgently required is that traversed by the Caledonian Canal; and therefore a letter similar to the one already quoted was addressed to the gentleman who, our Secretary was informed, was in charge of the Canal. As, however, the letter has not been acknowledged, our efforts in that direction have been futile.

It is generally the case that expenditure on the part of this Association leads to equal or greater expenditure for similar objects by other persons. This has been specially the case with rainfall work, and an illustration may be quoted from the events of last year. Simultaneously with the above action of the Committee, the Earl of Breadalbane (through his agent Mr. J. P. Smith, C.E.) has undertaken to supply returns from a series of stations between Aberfeldy and Tyndrum and other important localities in the watershed of the Tay and Rannoch. Several of the gauges were fixed by our Secretary, and the sites for others selected by him; and if the observations are regularly taken they will be of great utility.

A very limited number of gauges have also been supplied to remote districts of England and Wales; but the price of rain-gauges is now so low, that there can be but few persons, who are able and willing to take charge of a gauge, to whom the cost can be prohibitory. Your Committee are fully aware that in many parts of the country additional observations are desirable; but there are so many expenses incidental to the collection of the observations and their discussion, that they do not feel justified, considering the very limited means at their disposal, in lending gauges except to very isolated stations. Their Secretary will, however, be happy to render any information or assistance in his power to persons who may be willing to set up gauges; and it is hoped that by the maintenance and development of the present organization, these vacant spaces may gradually be occupied.

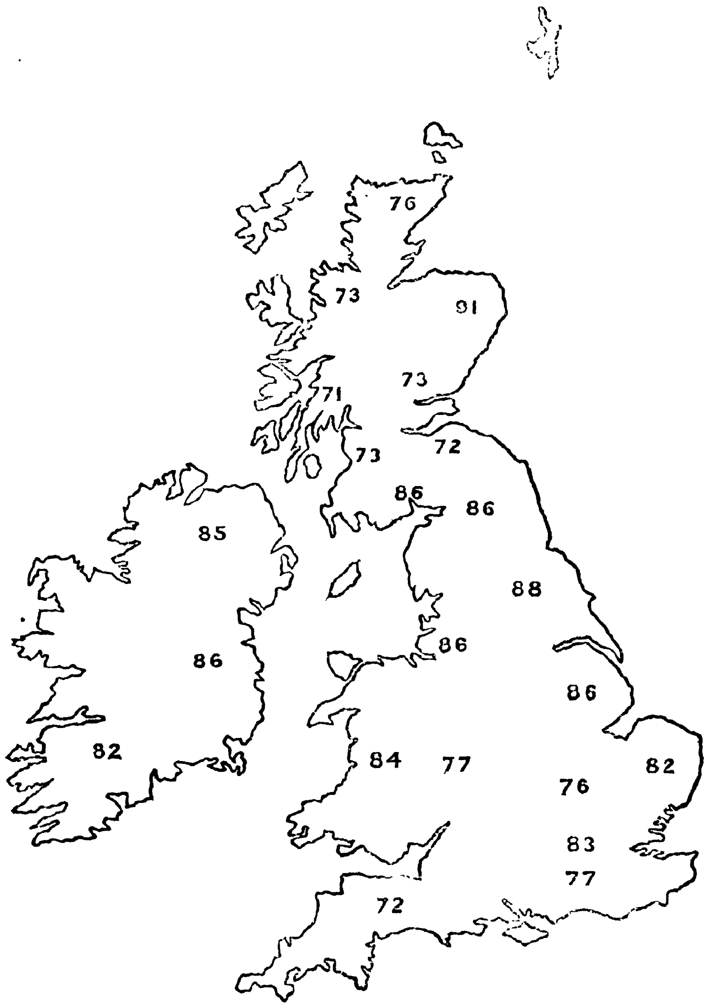
Owing to the illness of our Secretary, the forms of inquiry respecting the positions &c. of all the rain-gauges in the country (not only of those belonging to this Association, but also of the much more numerous private ones) were not issued as soon as was originally intended. About 1000 are, however, now circulated, and the rest will follow in less than a month. Those which have been returned have nearly all been filled up in a very complete and satisfactory manner, auguring well for the success of the proposal.

Another step taken with the same object, viz. the attainment of precise knowledge respecting the gauges in use, their errors and position, has been taken during the past year. Our Secretary has long possessed a travelling-case containing the standard measures necessary for verifying any rain-gauge without removing it from its position; and in previous reports we have given the results of several hundred examinations of rain-gauges *in situ* made with this apparatus. Owing, however, to our limited funds, this examination has been obliged to be curtailed; and as a partial counterpoise to this curtailment, we have caused to be constructed a precisely similar testing-case, and presented it to the Scottish Meteorological Society, whose Secretary will in future

use it in his inspections of the stations of that Society, and will communicate the results to us. We shall thus obtain a large amount of very valuable information at the mere original cost of the apparatus.

Ratio of Rainfall in the British Isles in 1870 to Mean (1860–69=100).

1870.



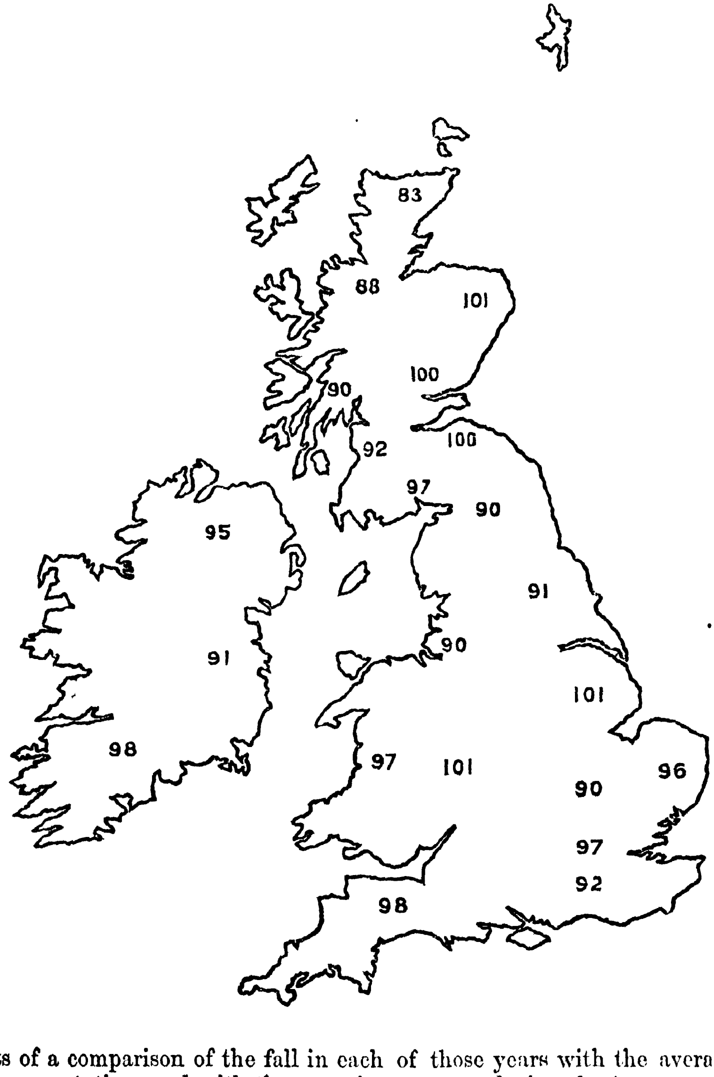
We regret that, owing to the cause already referred to, the discussion of the monthly percentages during 1860–69 is not quite ready for publication; the means are all taken, and the whole of the percentages (some 4000) are worked

out; the subsequent discussion will, we hope, be completed long before it is required for our next Report.

The only remaining subjects to which we have to direct attention are the biennial tables for 1870–71, which are given in the Appendix, and the re-

Ratio of Rainfall in the British Isles in 1871 to Mean (1860–69=100).

1871.



sults of a comparison of the fall in each of those years with the averages at the same stations and with the same instruments during the ten years 1860–69, given in our last Report. This is given in Table I., and an abstract of the same in Table II.

Among the many points of interest brought out by this mode of treatment, perhaps the only one to which we need call special attention is the general distribution of rain during 1870 and 1871. And first respecting 1870: the accompanying sketch map (p. 179) shows that there were two areas in which great deficiency of rain occurred, and that there was no division in which the fall reached the average. The areas of deficiency were the south-west of England and the west of Scotland; and on reference to Table I. it will be found that several stations in those divisions had less than two thirds of their average fall. The divisions in which the fall most nearly approached the average were the north-east of Scotland and Yorkshire, the latter owing to a very heavy local fall in North Lincolnshire, in October 1870, having partially extended into the former county.

In 1871 the fall was not very much below the average (only 5 per cent.), and the chart does not reveal such prominent features as in 1870. The greatest differences are found in the two sides of the north of Scotland, no other division differing more than 6 per cent. from the mean of the whole; and even this is mainly due to a belt of excess running north-eastward across the centre of England. This belt, moreover, is due to a single rain, that of September 6th, which in South-east Yorkshire amounted to nearly four inches, and to between one and two inches at nearly all stations thence south-westward to Devonshire. The area of that rain, it may be as well to state (including only those parts at which upwards of an inch fell), was about 14,000 square miles; and taking the fall at the low average of one and a half inch, not less than 1,357,000,000 (thirteen hundred and fifty-seven million) tons of water fell during the twenty-four hours.

TABLE I.*—Comparison of Rainfall, 1870 and 1871, with Average, 1860-69.

Division.	Station.	Mean, 1860-69.	Total Fall in 1870.	Total Fall in 1871.	Ratio of Fall. (1860-69=100.) 1870.	Ratio of Fall. (1860-69=100.) 1871.	Mean Divisional Ratio. 1870.	Mean Divisional Ratio. 1871.
		in.	in.	in.				
I.	Camden Square	25·68	21·32	25·02	83	97	83	97
II.	Weybridge Heath	25·05	19·55	23·22	78	93		
	Tanfield Lodge	26·33	21·69	24·18	82	92		
	Waldronhurst	24·39	19·80	20·24	81	83		
	Wimbledon	23·48	18·22	22·50	78	96		
	Kew Observatory	23·28	16·64	21·44	72	92		
	Linton Park	27·56	21·69	25·12	79	91		
	Hunton Court	26·00	20·49	22·94	79	88		
	West Thorney	26·88	20·58	26·19	77	97		
	Chichester Museum	29·03	21·37	25·86	74	89		
	,, Shopwyke	29·19	24·89	26·19	85	90		
	,, West Dean	37·08	28·35	34·39	76	93		
	,, Chilgrove	33·22	27·57	33·19	83	100		
	Dale Park	33·73	27·40	29·87	81	89		
	High Wickham	26·37	24·61	26·74	93	101		
	Forest Lodge	31·48	24·02	30·45	76	97		
	Osborne	30·73	21·96	29·26	72	95		
	Fareham	33·91	24·52	29·07	72	86		
	Petersfield	38·03	28·05	34·72	74	91		
	Selborne	34·43	26·89	33·43	78	97		
	Aldershot	27·04	22·94	25·59	85	95		

* Full particulars respecting the counties in which these stations are, and the heights of the rain-gauges above the ground and above sea-level, will be found on p. 106 of our last Report.

TABLE I. (*continued*).

Division.	Station.	Mean, 1860–69.	Total Fall in 1870.	Total Fall in 1871.	Ratio of Fall. (1860–69=100.) 1870.	Ratio of Fall. (1860–69=100.) 1871.	Mean Divisional Ratio.
		in.	in.	in.			
II.	Reading	25·73	16·85	22·14	65	86	
	Long Wittenham	27·38	16·88	21·52	62	79	77 92
III.	Bayfordbury	25·01	18·12	23·42	72	94	
	St. Albans	27·85	23·56	24·43	85	88	
	Hemelhempstead	26·39	21 64	23·49	82	89	
	Tring	27·59	24·40	23·69	88	86	
	Hitchin	23·92	17·76	20·84	74	87	
	Royston	23·57	17·16	19·07	73	81	
	High Wycomb	25·71	18·81	20·94	73	81	
	Radcliff Observatory	26·13	17·56	21·14	67	81	
	Banbury	26·22	19 93	24·80	76	95	
	Althorp House	23·35	17·21	22·43	74	96	
	Wellingborough	24·09	17·21	20·17	71	84	
	Kimbolton	23 13	16 47	21·73	71	94	
	Cardington, 0 ft. 0 in.	22 49	15·87	21·20	70	94	
	„ 3 ft. 6 in.	21·76	14·87	19·69	69	91	
	„ 36 ft. 0 in.	18·17	12 86	16·53	71	91	
	Ely	20·61	17 40	20·33	84	99	
	Wisbeach	24·04	20·71	24·77	86	103	76 90
IV.	Witham	20 47	18·77	20·77	92	101	
	Dunmow	22·75	17·11	21·66	75	95	
	Braintree	23·98	18·99	22·73	79	95	
	Saffron Walden	23·06	17 27	21 46	75	93	
	Hadleigh	25·47	18·14	21·83	71	86	
	Abbeygate St.	23·96	15 78	19·55	66	82	
	Westley	23·52	17 43	22·80	74	97	
	Barton Hall	23 68	17·58	22 61	74	95	
	Culford	24 83	18·94	24·78	76	100	
	Dickleburgh	22·22	19·35	21·85	87	98	
	Outwell	22·64	16 61	18·37	73	81	
	Fincham	23·14	20 50	23·14	89	100	
	Norwich Institution	22·17	18 87	23·13	85	104	
	Cossey	24·04	21 29	24·02	89	100	
	Honingham Hall	23·98	21·44	24·56	89	102	
	Egmere	25·10	24·41	24 47	97	97	
	Holkham, 0 ft. 0 in.	23 38	20·74	22·28	87	93	
	„ 4 ft. 0 in.	23·23	20·20	21·01	87	90	
	Hunstanton	19·56	18·36	21·45	94	110	82 96
V.	Salisbury Plain	29 28	22·59	28·06	77	96	
	Swindon	28·59	20·10	28·14	70	98	
	Bridport	32·25	20·32	30·84	63	96	
	Saltram	44 81	31·31	46·88	70	105	
	Ham	42·89	30·27	45·75	71	107	
	Ridgeway	48 65	32·17	47·72	66	98	
	Tavistock Library	43 36	36·89	51·88	85	120	
	„ West-street	53·17	37·40	53·40	70	100	
	Bovey Tracey	43·13	30·32	40·97	70	95	
	Coryton Lew Down	45·94	38 26	46·93	83	102	
	Exeter Institution	31·76	21·74	32·50	68	102	
	Clyst Hydon	32·69	22·98	32 21	70	99	
	Bradninch	38·06	22·20	33·10	58	87	
	Broadhembury	34·56	22·48	34·38	65	99	
	South Molton	47·12	33·12	36·80	70	78	
	Barnstaple	39·91	28·79	38·00	72	95	
	Helstone	37·87	27·66	41·60	73	110	
	Penzance	41·51	31·65	44·71	76	108	

TABLE I. (*continued*).

Division.	Station.	Mean, 1860–69.	Total Fall in 1870.	Total Fall in 1871.	Ratio of Fall. (1860–69 = 100.) 1870.	Ratio of Fall. (1860–69 = 100.) 1871.	Mean Divisional Ratio.
		in.	in.	in.			
V.	Redruth	41·23	37·00	39·92	90	97	
	Truro R. Institution	42·88	29·43	39·85	69	93	
	,, Penarth	42·56	28·54	40·96	67	96	
	Bodmin	47·71	39·73	49·12	83	103	
	Warleggan	54·56	44·21	48·75	81	89	
	Wadebridge	39·30	23·16	30·16	59	77	
	E. Harptree	42·10	35·35	40·52	84	96	72 98
VI.	Small Street	30·55	21·41	26·31	70	86	
	Clifton	34·09	23·43	29·10	69	85	
	Quedgeley	27·42	19·15	27·96	70	102	
	Archenfield	28·21	20·18	29·41	72	104	
	Rocklands	33·59	26·20	33·77	78	100	
	Leominster	27·11	18·87	27·76	70	102	
	Burford	26·74	20·23	31·25	76	117	
	Ludlow	28·53	21·91	30·02	77	105	
	Shiffnall	24·87	21·48	26·06	86	105	
	Shrewsbury	19·50	16·80	21·45	86	110	
	Oswestry	35·65	31·26	36·00	88	101	
	Northwick Park	28·02	21·76	27·63	78	99	
	Orleton	30·90	24·17	30·99	78	100	77 101
VII	Wigston	25·17	18·27	24·28	73	97	
	Thornton	25·61	19·33	26·10	76	102	
	Belvoir Castle	24·48	19·28	23·54	79	96	
	Grantham	22·41	17·12	22·19	76	99	
	Lincoln	20·87	16·29	19·12	78	92	
	Market Rasen	23·43	25·26	23·15	108	99	
	Gainsborough	21·66	16·44	22·37	76	103	
	Stockwith	21·35	18·42	23·05	86	108	
	Brigg	24·12	24·06	24·17	100	100	
	Grimsby	21·39	20·10	22·68	94	106	
	Barnetby	22·16	26·90	27·65	121	125	
	Appleby Vicarage	24·10	23·20	25·66	96	107	
	New Holland	22·67	23·67	24·56	104	109	
	Southwell	20·84	16·33	19·02	78	91	
	Welbeck Abbey	24·64	21·58	25·48	87	103	
	Worksop	22·47	18·08	25·31	81	113	
	Retford	22·74	17·02	23·49	75	103	
	Derby	26·81	18·73	28·70	70	107	
	Chesterfield	26·93	21·00	26·56	78	99	
	Kilnarsh	24·59	19·07	27·15	77	110	
	Combs Moss	49·62	40·24	46·12	81	93	
	Combs Reservoir	50·01	47·58	45·14	95	90	
	Chapel-en-le-Frith	41·95	37·90	41·55	90	99	
	Woodhead	52·19	42·21	40·93	81	78	86 101
VIII.	Bosley Minns	32·85	26·49	32·86	81	100	
	,, Reservoir	32·04	24·33	29·82	76	93	
	Macclesfield	34·54	23·83	36·34	69	105	
	,, Park Green	36·75	29·01	32·82	79	89	
	Bollington	37·46	26·80	32·40	72	86	
	Whaley	43·89	39·90	38·54	91	88	
	Marple Aqueduct	34·81	30·01	25·70	86	74	
	,, Top Lock	35·25	32·98	27·74	94	79	
	Godley Reservoir	33·98	30·04	31·45	88	93	
	Mottram	37·73	32·28	34·20	86	91	
	Newton	31·63	30·30	31·18	96	99	
	Arnfield	37·23	34·45	33·88	93	91	

TABLE I. (*continued*).

Division.	Station.	Mean, 1860–69.	Total Fall in		Ratio of Fall. (1860-69=100.)		Mean Divisional Ratio.	
			1870.	1871.	1870.	1871.		
		in.	in.	in.				
VIII.	Rhodes Wood	46·32	39·88	38·99	86	84		
	Woodhead...............	51·83	46·62	43·73	90	84		
	Denton	32·97	28·08	29·16	85	89		
	Gorton	33·71	28·93	29·58	86	88		
	Old Trafford	34·73	29·55	33·23	85	96		
	Ardwick..................	32·60	30·54	33·64	94	103		
	Piccadilly	36·78	27·67	29·18	75	79		
	Fairfield..................	40·90	33·44	36·30	82	89		
	Waterhouses	36·13	33·64	36·91	93	102		
	Oldham Gas-Works...	37·12	32·49	32·11	87	86		
	Strines Dale	36·01	31·35	33·86	87	94		
	Bolton (The Folds) ...	48·98	43·47	40·93	89	84		
	Belmont.....	56·61	52·80	46·80	93	83		
	Heaton	44·21	41·10	40·40	93	91		
	Rochdale	44·13	35·18	34·65	80	78		
	Ormskirk	35·00	29·84	31·95	85	89		
	Preston	38·30	34·17	34·25	89	89		
	Blackpool	32·99	31·41	29·94	95	91		
	Stonyhurst...............	48·56	45·56	43·91	94	91		
	Clitheroe	44·79	38·05	38·25	85	86		
	Lancaster	43·94	39·67	39·59	90	90		
	Cartmel	45·63	39·24	42·41	86	93	86	90
IX.	Broomhall Park	31·28	26·01	30·63	83	98		
	Redmires	39·68	33·46	34·82	84	88		
	Tickhill	23·99	20·68	26·44	86	110		
	Dunford Bridge	56·18	54·44	46·93	97	84		
	Saddleworth	41·97	38·11	37·73	91	90		
	Standedge	53·70	47·75	42·25	89	79		
	Longwood	34·01	24·14 ?	19·04 ?	71 ?	56 ?		
	Warley Moor	46·33	36·10	35·80	78	77		
	Well Head	33·31	29·59	27·90	89	84		
	Midgeley Moor	50·00	42·30	39·60	85	79		
	Ovenden Moor	46·09	35·30	36·70	77	79		
	Leventhorpe	23·26	21·99	25·36	94	109		
	Holbeck	22·85	20·50	22·80	90	100		
	York	24·48	24·37	28·68	100	117		
	Arncliffe.............. ..	60·08	50·14	52·73	83	88		
	Hull	25·02	25·81	25·68	103	102		
	Malton	27·46	26·32	27·76	96	101		
	Richmond	31·11	25·95	29·05	83	93	88	91
X.	Shotley Hall	28·49	25·38	26·96	89	94		
	Bywell	28·87	25·84	33·53	89	116		
	Wylam	26·90	24·43	26·69	91	99		
	Wallsend	26·64	23·90	25·87	90	97		
	Rosella Place...........	26·07	25·22	26·18	97	100		
	Stamfordham	27·64	26·15	26·51	95	96		
	Lilburn Tower	28·66	23·27	25·44	81	89		
	Seathwaite..............	154·05	119·60	115·15	78	75		
	Ullswater	59·91	50·70	45·80	85	76		
	Bassenthwaite .. [Hall	53·76	48·97	40·12	91	75		
	Cockermouth, Whinfell	57·37	48·86	41·70	85	73		
	Carlisle	27·62	20·50	23·58	74	85		
	Kendal	53·32	43·09	50·25	81	94		
	Appleby	35·99	27·31	31·80	76	88	86	90
XI.	Cardiff	42·02	35·60	41·16	85	98		
	Rhayader	44·98	41·35	43·93	92	98		

TABLE I. (*continued*).

Division.	Station.	Mean, 1860–69.	Total Fall in 1870.	Total Fall in 1871.	Ratio of Fall. (1860–69=100.) 1870.	Ratio of Fall. (1860–69=100.) 1871.	Mean Divisional Ratio. 1870.	Mean Divisional Ratio. 1871.
		in.	in.	in.				
XI.	Hawarden	26·44	23·29	28·22	88	107		
	Holywell	24·43	22·91	24·63	94	101		
	Llandudno	31·00	27·43	30·56	89	99		
	Isle of Man	30·61	23·89	24·21	78	79		
	Guernsey	37·18	25·05	36·26	68	98		
	Alderney	28·62	21·05	27·18	74	95	84	97
	SCOTLAND.							
XII.	Mull of Galloway	27·66	21·58	24·22	78	88		
	Stranraer	49·60	62·25	56·15	126	113		
	Corsewall	37·03	32·05	34·88	87	94		
	Little Ross	26·98	22·95	27·60	85	102		
	Cargen	44·37	39·97	44·54	90	100		
	Dumfries	37·05	28·32	35·32	77	95		
	Westerkirk	60·09	47·68	52·20	79	87		
	Wanlockhead	66·63	49·31	(59·74)	74	(90)		
	Kelso	24·66	19·27	25·47	78	103	86	97
XIII.	Bowhill	33·03	25·06	31·23	76	95		
	Penicuick	38·01	23·65	34·30	62	90		
	Lauder	29·98	22·40	31·60	75	105		
	Dunse	28·49	23·85	29·28	84	103		
	Haddington	25·63	19·33	25·42	76	99		
	East Linton	23·77	19·30	25·62	81	108		
	Cobbinshaw	37·45	23·50	36·40	63	97		
	Inveresk	29·02	16·50	30·42	57	105	72	100
XIV.	Auchinraith	31·95	21·76	32·02	68	100		
	Bothwell Castle	28·89	21·19	28·22	73	98		
	Cessnock Park	37·96	26·62	34·00	70	90		
	Glasgow Observatory	44·41	35·25	40·54	80	91		
	Baillieston	46·47	36·17	45·69	78	98		
	Shotts	33·45	24·13	26·53	72	79		
	Ayr	44·83	33·22	40·17	74	89		
	Largs	48·92	40·80	42·80	83	88		
	Ryatt Lynn	47·80	33·75	46·60	71	97		
	Waulk Glen	49·85	33·35	46·15	67	93		
	Middleton	56·68	40·25	50·70	71	89		
	Mearns	50·14	36·69	47·88	73	95		
	Greenock	66·16	47·00	62·31	71	94	73	93
XV.	Arddaroch	78·32	59·15	71·40	75	91		
	Falkirk	32·96	21·50	32·20	65	98		
	Stirling	41·30	26·65	38·10	65	92		
	Pladda	40·14	27·63	37·18	69	93		
	Castle Toward	54·55	41·06	48·10	75	88		
	Lochgilphead	54·25	50·26	52·28	92	96		
	Inverary	67·37	42·00	41·50	62	62		
	Appin	63·64	53·30	50·70	84	80		
	Ardnamurchan	45·59	30·98	37·61	68	83		
	Mull of Cantire	44·17	33·16	45·77	75	104		
	Campbeltown	47·31	38·32	45·00	81	95		
	Rhinns of Islay	33·43	25·42	34·76	76	104		
	Lismore	46·22	31·67	35·78	68	77		
	Sound of Mull	72·16	24·43	89·20	34	121		
	Hynish	79·99	59·53	57·38	75	72	71	90
XVI.	Loch Leven	35·78	21·40	34·10	60	95		
	Balfour	28·59	23·41	34·14	82	119		
	Leven	28·99	21·69	30·94	75	107		

TABLE I. (*continued*).

Division.	Station.	Mean, 1860–69.	Total Fall in 1870.	Total Fall in 1871.	Ratio of Fall. (1860–69=100.) 1870.	Ratio of Fall. (1860–69=100.) 1871.	Mean Divisional Ratio.
		in.	in.	in.			
XVI.	Aberfoyle	61·82	40·60	60·60	66	98	
	Dunblane	36·17	23·70	32·40	66	90	
	Deanston House	43·99	30·22	41·81	69	95	
	Lanrick Castle	48·81	28·90	40·90	59	84	
	Bridge of Turk	61·89	46·10	64·10	74	104	
	Auchterarder House	34·32	24·05	31·85	70	93	
	Trinity Gask	35·32	24·59	34·69	70	98	
	Stronvar	82·43	61·33	75·57	74	92	
	Perth Academy	23·58	15·94	21·35	68	91	
	Scone Palace	29·18	21·39	29·67	73	102	
	Barry	29·73	24·22	33·64	82	113	
	Craigton	34·88	29·65	40·41	85	116	
	Kettins	33·17	27·11	33·62	82	101	
	Hill Head	35·19	29·48	39·15	84	111	
	Arbroath	29·05	22·40	26·69	77	92	73 100
XVII.	Brechin	34·91	28·70	33·20	82	95	
	Girdleness	22·72	19·49	20·61	86	91	
	Braemar	33·40	30·38	30·35	91	91	
	Aberdeen	29·43	24·00	25·18	82	86	
	Kinnairdhead	24·17	30·28	34·65	125	143	
	Gordon Castle	29·19	23·56	28·83	81	99	91 101
XVIII.	Stornoway	31·79	24·22	27·81	76	87	
	Bernera	68·03	37·90	52·10	56	77	
	Cromarty	25·94	16·28	20·87	63	81	
	Oronsay	72·36	34·95	49·48	48	69	
	Kyleakin	82·07	49·07	61·70	60	75	
	Raasay	77·12	55·40	70·10	71	91	
	Barrahead	31·73	25·62	30·89	81	97	
	S. Uist	43·91	42·78	37·86	97	86	
	Harris	31·13	33·51	42·57	107	137	
	Culloden House	27·08	17·91	20·76	66	77	73 88
XIX.	Dunrobin Castle	27·69	26·76	24·75	97	89	
	Cape Wrath	39·37	29·26	33·12	74	84	
	Wick	24·70	22·06	18·91	89	77	
	Pentland Skerries	28·76	19·64	21·36	68	74	
	Hoy, East	39·01	27·34	33·22	70	85	
	Hoy, West	32·69	17·63	18·53	54	57	
	Balfour Castle	32·41	29·60	26·40	91	81	
	Sandwick	38·85	30·72	32·17	79	83	
	Sanda	31·37	29·76	38·64	95	123	
	North Ronaldsay	31·02	14·40	17·04	46	55	
	Sumburghead	26·45	21·19	23·69	80	90	
	Bressay, L. H.	36·49	24·48	33·84	67	93	76 83
	IRELAND.						
XX.	Cork	34·77	28·46	35·66	82	102	
	Fermoy	37·21	29·09	35·56	78	96	
	Waterford	40·67	33·55	44·67	83	110	
	Killaloe	47·65	40·78	40·70	85	85	82 98
XXI.	Portarlington	36·86	26·04	28·51	71	77	
	Tullamore	27·94	24·86	29·09	89	104	
	Bray	41·82	33·14	33·25	79	79	
	Black Rock	27·10	25·02	28·11	92	104	83 91
XXIII.	Enniskillen	44·37	42·97	46·29	97	104	
	Armagh	32·01	22·29	28·40	70	89	
	Belfast, Queen's Coll.	34·23	30·14	31·91	88	93	85 95

TABLE II.—Mean and Extreme Ratios in each Division.

Division.	Description.	Number of Stations.	Ratio for 1870. Mean.	Ratio for 1870. Highest.	Ratio for 1870. Lowest.	Ratio for 1871. Mean.	Ratio for 1871. Highest.	Ratio for 1871. Lowest.
	ENGLAND AND WALES.							
I.	Middlesex	1	83	83	83	97	97	97
II.	South-Eastern Counties	22	77	93	62	92	101	79
III.	South Midland Counties	17	76	88	67	90	103	81
IV.	Eastern Counties	19	82	97	66	96	110	81
V.	South-Western Counties	25	72	90	58	98	120	78
VI.	West Midland Counties	13	77	88	69	101	117	85
VII.	North Midland Counties	24	86	121	70	101	125	78
VIII.	North-Western Counties	34	86	96	69	90	105	74
IX.	Yorkshire	18	88	103	71	91	117	56
X.	Northern Counties	14	86	97	74	90	116	73
XI.	Monmouthshire, Wales, &c	8	84	94	68	97	107	79
	SCOTLAND.							
XII.	Southern Counties	9	86	126	74	97	113	87
XIII.	South-Eastern Counties	8	72	84	57	100	108	90
XIV.	South-Western Counties	13	73	83	67	92	100	88
XV.	West Midland Counties	15	71	92	34	90	121	62
XVI.	East Midland Counties	18	73	85	59	100	119	84
XVII.	North-Eastern Counties	6	91	125	81	101	143	86
XVIII.	North-Western Counties	10	73	107	56	88	137	69
XIX.	Northern Counties	12	76	97	46	83	123	57
	IRELAND.							
XX.	Munster	4	82	85	78	98	110	85
XXI.	Leinster	4	83	103	71	91	104	77
XXIII.	Ulster	3	85	97	70	95	104	89
	Mean	Total 297	80	97	66	95	114	79
	Maximum		91	126	83	101	143	97
	Minimum		71	83	34	83	97	56

TABLES OF MONTHLY RAIN-

ENGLAND.

	Division I.—Middlesex.								Div. II.-S.E. Counties.			
	Middlesex.								Surrey.			
Height of Rain-gauge above	Camden Square.		Upper Clapton.		Hampstead, Squire's Mount.		Winchmore Hill.		Dunsfold, Godalming.		Weybridge Heath.	
Ground	0 ft. 4 in.		1 ft. 1 in.		1 ft. 0 in.		1 ft. 0 in.		2 ft. 6 in.		0 ft. 6 in	
Sea-level......	111 ft.		91 ft.		385 ft.		350 ft.		166 ft.		150 ft.	
	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
January	1·38	1·99	1·46	1·89	1·40	1·79	1·46	1·69	1·71	2·74	1·54	2·22
February ...	1·21	1·27	1·02	1·32	1·18	1·33	1·47	1·55	2·70	1·43	1·87	·97
March	2·31	1·19	1·96	1·32	2·09	1·12	1·76	1·53	1·82	1·43	2·23	1·31
April	·47	2·84	·42	2·79	·53	3·12	·43	2·69	·20	3·39	·32	3·78
May	·70	·92	·62	·65	·85	1·09	1·06	·85	1·36	·29	·75	·36
June	·83	3·49	·56	3·60	·77	2·48	·86	2·50	·61	2·28	·59	2·99
July	1·22	4·12	·98	3·67	1·52	3·90	·63	3·54	3·01	3·73	1·03	3·66
August	2·69	·85	2·63	·73	1·97	·89	2·18	·72	2·08	1·36	2·19	·97
September ...	2·00	5·28	1·98	5·22	2·15	4·83	2·04	4·98	2·84	5·49	1·71	4·27
October	3·68	1·34	3·48	1·26	3·50	1·25	4·00	1·02	3·66	1·20	3·12	1·11
November ...	1·76	·60	1·52	·56	1·36	·52	1·20	·66	1·83	·43	1·24	·37
December ...	3·07	1·13	2·98	1·06	2·80	1·15	2·99	1·44	2·82	1·43	2·96	1·21
Totals	21·32	25·02	19·61	24·07	20·12	23·47	20·08	23·17	24·64	25·20	19·55	23·22

	Division II.—South-Eastern Counties (*continued*).											
	Kent (*continued*).						Sussex.					
Height of Rain-gauge above	River Head, Sevenoaks.		Acol, Margate.		Sidcup, Foots Cray.		Brighton, Lewes Road.		West Thorney.		Chichester Museum.	
Ground	1 ft. 0 in.		1 ft. 0 in.		0 ft. 8 in.		3 ft. 9 in.		0 ft. 8 in.		0 ft. 6 in.	
Sea-level......	....		60 ft.		231 ft.		90 ft.		10 ft.		50 ft.	
	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
January	2·43	4·10	·92	2·85	1·09	2·76	1·79	2·98	3·42	4·05	1·69	3·09
February ...	1·99	1·93	·32	·61	·86	1·00	1·87	1·76	2·57	1·09	2·48	1·34
March	2·11	1·76	1·24	1·01	2·16	1·11	1·78	1·02	·30	·57	1·43	·83
April	·39	3·71	·30	2·06	·33	2·86	·51	4·55	·00	2·20	·17	4·12
May	1·37	·66	1·11	·69	·67	·79	·90	·19	1·76	·57	·90	·15
June	·63	2·81	1·31	2·63	·46	2·76	·29	4·03	·00	3·55	·24	3·11
July	1·39	3·37	1·19	2·05	1·41	3·35	·76	3·76	·98	4·48	1·94	3·98
August	1·91	2·49	1·16	·93	1·67	1·00	2·50	1·55	1·51	1·60	2·13	1·41
September ...	2·21	4·71	2·16	3·28	2·21	5·02	3·02	3·46	1·31	4·47	1·61	4·51
October	6·05	1·92	3·13	1·14	3·07	·99	5·21	1·69	3·95	1·76	4·38	1·32
November ...	2·09	·89	1·25	·68	1·42	·49	2·70	·77	2·14	·35	1·79	·94
December ...	3·75	2·17	2·29	1·82	3·28	1·22	4·09	1·56	2·64	1·50	2·61	1·06
Totals	26·32	30·52	16·38	19·75	18·63	23·35	25·42	27·32	20·58	26·19	21·37	25·86

FALL IN THE BRITISH ISLES.

ENGLAND.

Division II.—South-Eastern Counties (*continued*).

Surrey (*continued*).						Kent.							
Chobham.		Kew Observatory.		Kennington Road.		Dover, Castle St.		Hythe.		Linton, Maidstone.		Falconhurst, Edenbridge.	
1 ft. 2 in. 93 ft.		1 ft. 3 in. 19 ft.		5 ft. 0 in. 19 ft.		2 ft. 2 in. 30 ft.		0 ft. 6 in. 12 ft.		0 ft. 6 in. 296 ft.		1 ft. 0 in. 400 ft.	
1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.
in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
1·26	2·19	1·23	1·76	1·01	1·54	2·44	3·32	2·41	3·13	1·66	3·50	1·90	3·73
2·00	·95	1·27	·99	·50	1·02	·45	1·83	·84	2 23	1·14	1 07	2·49	1·80
1·75	1·16	1 78	·98	1·84	·89	1 93	1·42	1·57	1·84	1·64	1·44	2·48	1·80
·46	3·39	·40	2·69	·38	2·41	·34	4 59	·43	4 03	·43	2·80	·43	3·60
·90	·29	·82	·79	·47	1·10	1 27	·83	1 82	1·03	1·14	1·20	1·11	1·14
·51	3·51	·56	2·98	1·00	3·76	·32	2 67	·71	3·15	·32	2 92	·49	3·15
·55	2·84	·65	3·23	1 58	4·05	·72	2·42	1·31	2·92	1·95	2·84	2·59	3·24
1·77	1·00	2·02	·95	2 00	·68	1·31	·88	1 23	·84	2·06	1·09	1 72	1·63
1·37	3·73	1·37	4·42	2·00	4·84	1·71	4 67	2 39	4 66	2·08	4 44	2·80	4·07
2·94	1·19	2·57	1·02	3·16	·82	4 60	1·40	4 90	1 77	3 89	1·44	4·64	1·58
1·58	·33	1·36	·51	1·75	·35	3·96	3·04	3·53	2·01	1 70	·76	2·44	·69
2·48	1·24	2·61	1·12	2·17	·86	4·19	3 20	4·36	2·83	3·68	1·62	4·11	1·99
17·57	21·82	16 64	21·44	17·86	22 32	23·24	30 27	25·50	30·44	21 69	25·12	27·20	28·42

Division II.—South-Eastern Counties (*continued*).

Sussex (*continued*).												Hampshire.	
Bleak House, Hastings.		Dale Park, Arundel.		Battle.		Chilgrove, Chichester.		Balcomb Place, Cuckfield.		Petworth Rectory.		St. Lawrence, Isle of Wight.	
1 ft. 3 in. 77 ft.		3 ft. 5 in. 316 ft.		1 ft. 3 in.		0 ft. 6 in. 284 ft.		1 ft. 3 in. 300 ft.		2 ft. 0 in. 190 ft.		1 ft. 0 in. 75 ft.	
1870.	1871.	1870.	1871.	1870	1871.	1870.	1871.	1870.	1871	1870	1871.	1870	1871.
in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
2·52	2·07	2·52	2·85	2·55	2·62	2·40	3·53	2·17	4·33	1·85	3·21	1·83	3·18
1·02	1·48	2·40	1·84	1·39	1·46	3·38	1·94	2·44	2·31	3 66	1 85	2·20	1·35
1·97	1·32	1·88	1·28	1·96	1·62	2 08	1·47	2 06	1·74	2·21	1·92	1·79	·96
·32	3·96	·10	5·02	·41	4·76	·21	4·78	·30	4 10	·23	3·60	·33	3·53
1·20	·90	1·30	·82	1·98	1·12	1·44	·61	1·10	·79	1·88	·28	1·23	·05
·43	1·51	·32	4·37	·66	2·45	·44	3·84	·28	2·64	·56	2·39	·25	2·02
·89	2·68	3·44	4·50	1·39	3·09	1·62	5·31	2·23	3 15	2·34	4·34	1·60	4·14
1·75	·96	2 63	1 50	2·08	1·20	} 5·66	1·76	2·70	1·93	1·80	1·36	1·24	1·46
2·39	3·66	2·21	3·70	3·55	3 96		5 08	2 87	4·18	2·36	4·82	1·59	5·70
4·96	1·42	5·77	1·84	5·24	1 43	4 81	1·76	5·06	1·25	5·64	1·53	4·59	2·09
2·73	·56	2·53	·85	2·81	·58	1·96	·85	2·32	·81	2·10	·48	2·28	·47
2·85	1·57	2·30	1·30	4·43	1 87	3·57	2·26	4·02	2·06	3·18	1·82	3·06	1·17
23·03	22·09	27·40	29·87	28·45	26·16	27·57	33·19	27·55	29·29	27·81	27·60	21·99	26·13

ENGLAND.

Division II.—South-Eastern Counties (*continued*).

Hampshire (*continued*).

Height of Rain-gauge above Ground …… Sea-level……	Ryde, Isle of Wight. 7 ft. 0 in. 20 ft.		Osborne, Isle of Wight. 0 ft. 8 in. 172 ft.		Fareham. 10 ft. 0 in. 36 ft.		Shirley Warren, Southampton. 4 ft. 0 in. 106 ft.		Selborne. 4 ft. 0 in. 400 ft.		Liss, Petersfield. 0 ft. 7 in. 250 ft.	
	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
January ……	1·81	3·25	1·81	3·30	2·73	2·60	2·63	2·12	2·00	3·12	2·58	2·41
February …	2·94	1·46	2·32	1·53	2·43	1·15	2·38	1·28	3·95	1·77	4·08	2·08
March ……	1·23	1·30	1·58	1·24	1·80	1·23	1·85	1·48	2·67	2·04	2·86	3·24
April ………	·21	4·09	·28	4·12	·19	3·98	·44	4·04	·35	4·55	·36	4·87
May ………	1·42	·19	1·42	·35	1·77	·50	1·39	·27	1·95	·20	1·77	·22
June ………	·19	2·68	·18	2·48	·17	3·05	·38	2·98	·52	3·77	·40	2·86
July ………	1·27	4·13	·72	4·07	·66	4·53	1·37	4·53	·49	4·43	·35	5·41
August ……	1·94	1·80	2·09	1·44	2·42	2·15	1·82	1·44	1·66	2·30	2·49	1·89
September ..	1·68	6·31	1·93	6·12	1·72	4·93	2·45	6·16	2·39	6·43	1·31	6·56
October ……	4·46	1·89	4·46	1·92	4·37	1·79	3·88	2·00	4·85	1·85	5·72	2·02
November …	2·83	·49	1·95	·49	2·24	1·32	2·04	·82	2·77	·57	2·66	·55
December ..	3·15	1·55	3·22	2·20	4·02	1·84	2·85	2·13	3·29	2·40	3·47	2·61
Totals ……	23·13	29·14	21·96	29·26	24·52	29·07	23·47	29·25	26·89	33·43	28·05	34·72

Division III.—South Midland Counties (*continued*).

	Buckinghamshire.		Northampton.				Bedford.		Cambridge.			
Height of Rain-gauge above Ground …… Sea-level……	High Wycomb. 0 ft. 9 in. 225 ft.		Althorpe House. 3 ft. 4 in. 310 ft.		Wellingborough. 0 ft. 3 in. …………		Cardington. 0 ft. 0 in. 106 ft.		Wisbech. 0 ft 6 in. 10 ft.		Outwell Sluice. 4 ft. 0 in. 16 ft.	
	1870.	1871.	1870.	1871.	1870.	1871.	1870	1871.	1870.	1871.	1870.	1871.
	in.	in.	in.	in.	in.	in.	in	in.	in.	in.	in.	in.
January ……	1·50	1·50	1·24	1·14	1·12	1·01	·70	·90	·97	·87	1·27	·46
February …	2·22	1·10	1·84	1·09	1·27	1·25	1·05	1·10	1·01	2·07	·47	1·39
March ……	1·71	1·13	·96	1·19	1·00	1·31	1·60	1·31	1·09	1·15	·69	·52
April ………	·29	2·94	·53	2·44	·63	2·45	·50	2·00	·75	3·07	·54	2·86
May ………	·93	·28	·63	·64	·65	·54	·65	1·20	·69	·74	·43	·73
June ………	·43	2·50	·81	3·94	·90	3·17	1·00	3·25	2·47	4·11	1·90	4·00
July ………	·86	2·72	1·65	4·17	2·17	3·80	1·60	3·25	2·04	3·52	3·29	1·89
August ……	1·87	·81	2·17	·79	2·16	·51	1·50	·60	1·46	1·35	1·41	·47
September …	2·17	5·10	1·10	4·04	·83	3·47	·80	4·90	1·96	3·92	1·15	3·21
October ……	3·03	1·03	3·14	1·28	3·07	·97	2·62	·84	3·28	1·35	2·37	1·04
November …	1·23	·62	1·27	·82	1·09	·81	1·00	1·00	1·38	1·39	·86	1·13
December ..	2·57	1·21	1·87	·89	2·32	·88	2·85	·85	3·39	1·28	2·23	·67
Totals………	18·81	20·94	17·21	22·43	17·21	20·17	15·87	21·20	20·49	24·82	16·61	18·37

ENGLAND.

Division II.—South-Eastern Counties (*continued*).				Division III.—South Midland Counties.									
Hampshire (*continued*).		Berkshire.		Hertfordshire.						Oxfordshire.			
Aldershot.		Long Wittenham.		Berkhampstead.		Royston.		Hitchin.		Radcliffe Observatory, Oxford.		Banbury.	
6 ft. 0 in. 316 ft.		1 ft. 0 in. 170 ft.		1 ft. 6 in. 370 ft.		0 ft. 6 in. 266 ft.		1 ft. 4 in. 238 ft.		0 ft. 8 in. 207 ft.		7 ft. 0 in. 350 ft.	
1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.
in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
1·75	2·17	1·30	1·47	1·60	1·80	·82	·67	1·17	1·17	1·16	1·11	1·33	1·13
2·58	1·33	1·82	1·16	2·82	1·55	1·00	1·30	1·36	1·20	1·91	·97	2·44	1·20
3·78	1·38	1·47	1·26	2·00	1·61	2·00	1·32	1·82	1·40	1·65	·95	1·49	1·33
·34	3·18	·63	2·05	·47	2·89	·38	2·18	·43	2·14	·53	2·61	·66	2·65
1·25	·52	·95	·76	1·17	1·12	·74	·97	·85	·92	1·03	·43	1·17	·98
·35	3·66	·50	2·61	·88	3·45	1·17	2·92	·79	2·43	·66	3·17	·75	3·99
·53	3·51	·73	4·18	1·66	3·32	1·48	2·10	1·20	3·67	·89	3·78	1·09	4·07
1·58	1·67	3·00	·50	3·01	·84	1·58	·43	1·23	·62	2·35	·50	1·73	·75
2·12	4·14	·77	4·26	2·21	5·28	1·50	4·90	1·55	4·40	1·32	4·66	1·33	5·41
3·68	1·74	2·95	1·36	4·58	1·14	2·73	·52	3·47	·81	2·91	1·19	3·84	1·20
1·80	·49	1·14	·48	1·56	·76	1·05	·88	1·29	·93	1·15	·70	1·90	·80
3·18	1·80	1·62	1·43	3·06	1·60	2·71	·88	2·60	1·15	2·00	1·07	2·20	1·29
22·94	25·59	16·88	21·52	25·02	25·36	17·16	19·07	17·76	20·84	17·56	21·14	19·93	24·80

Division IV.—Eastern Counties.													
Essex.										Suffolk.			
The Hemnalls, Epping.		Dorward's Hall, Witham		Dunmow.		Bocking, Braintree.		Ashdon Rectory.		Grundisburgh		Culford, Bury St. Edmund's.	
0 ft. 8 in. 345 ft.		1 ft. 6 in. ?20 ft.		0 ft. 0 in. 234 ft.		3 ft. 6 in. 200 ft.		1 ft. 0 in. 300 ft.		3 ft. 6 in.		1 ft. 2 in.	
1870.	1871.	1870.	1871.	1870.	1871	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.
in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
1·65	1·78	1·82	1·59	·98	1·40	1·07	1·72	·85	·74	1·01	1·22	·89	1·08
1·24	1·70	·97	1·29	·75	1·53	·83	1·76	1·87	1·77	·76	2·11	·78	2·07
1·59	1·61	1·83	1·40	1·68	1·20	2·13	1·11	1·78	1·10	1·96	·97	1·87	1·47
·30	2·75	·48	2·94	·40	2·60	·33	2·65	·52	2·37	·61	3·61	·78	3·70
1·22	·72	·56	1·14	·83	1·07	·90	·47	·49	·68	·75	·59	·36	1·63
·63	3·50	·28	2·26	·49	2·34	·61	2·54	·90	2·89	·42	2·51	·98	3·30
·88	2·67	1·15	2·68	·99	2·90	1·33	3·15	1·22	3·53	1·36	2·77	2·00	2·93
1·66	·83	2·75	·99	1·68	·65	2·17	·92	1·70	·53	1·76	·65	1·77	·29
2·54	4·60	1·93	3·61	2·31	4·42	1·55	4·53	1·39	4·47	1·49	3·74	1·58	4·40
3·65	1·16	2·94	·98	2·80	1·26	3·47	1·28	2·75	1·24	3·16	·63	3·03	1·40
1·34	·65	1·30	·25	1·00	·76	·83	·89	·90	·81	·63	1·85	·89	1·52
3·12	1·82	2·76	1·64	3·20	1·53	3·77	1·71	2·90	1·33	3·71	1·06	4·01	·99
19·82	23·79	18·77	20·77	17·11	21·66	18·99	22·73	17·27	21·46	17·62	21·71	18·94	24·78

ENGLAND.

	Division IV.—Eastern Counties (*continued*).								Division V.—South-Western Counties.			
•	Norfolk.								Wilts.			
Height of Rain-gauge above	Geldeston, Beccles.		Cossey, Norwich.		Egmere, Fakenham.		Holkham.		Wilton, Salisbury.		Marlborough College.	
Ground ...... Sea-level......	1 ft. 0 in. 40 ft.		1 ft. 0 in.		4 ft. 8 in. 150 ft.		0 ft. 0 in. 39 ft.		0 ft. 5 in. 150 ft.		0 ft. 0 in. 456 ft.	
	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
January	1·08	·95	1·21	·73	1·26	·43	·80	·50	2·35	2·89	1·87	2·92
February ...	·61	1·59	·80	1·88	·84	1·63	1·00	1·50	3·40	1·81	2·48	1·50
March	1·48	1·09	1·54	·96	1·96	·91	1·63	·68	1·89	1·61	2·06	1·35
April	·61	3·13	·88	3·12	·91	2·99	·95	3·05	·44	4·58	·54	3·83
May	·75	1·47	·61	1·03	·66	1·36	·45	1·50	1·21	·72	2·14	1·17
June	1·08	2·55	1·12	3·50	1·90	3·30	1·65	2·13	·40	1·98	·35	2·98
July	2·35	1·80	1·91	2·79	2·03	3·13	1·36	3·10	1·32	4·93	1·73	4·33
August	2·16	·91	2·18	·62	2·73	·51	2·20	·60	1·98	2·04	1·91	1·16
September ...	1·35	4·04	1·61	3·91	1·33	4·56	1·05	4·45	1·39	4·74	1·26	6·22
October	3·08	1·12	3·85	1·65	4·10	1·71	3·60	1·70	5·62	2·77	4·54	1·86
November ...	·77	2·50	1·43	2·55	1·90	2·26	1·95	1·95	2·70	·67	2·02	·66
December ...	3·95	1·03	4·15	1·28	4·79	1·68	4·10	1·12	2·55	2·92	2·51	2·48
Totals	19·27	22·18	21·29	24·02	24·41	24·47	20·74	22·28	25·25	31·66	23·41	30·46

	Division V.—South-Western Counties (*continued*).											
	Devonshire (*continued*).											
Height of Rain-gauge above	Landscore, Teignmouth.		Broadhembury, Honiton.		Cove, Tiverton.		Castle Hill, S. Molton.		Great Torrington.		Barnstaple.	
Ground ...... Sea-level......	0 ft. 6 in. 200 ft.		1 ft. 6 in. 400 ft.		0 ft. 4 in. ? 400 ft.		3 ft. 5 in. ? 200 ft.		1 ft. 1 in. 323 ft.		0 ft. 6 in. 31 ft.	
	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
January	2·06	2·69	2·08	2·96	2·92	4·40	2·99	4·20	2·96	2·93	3·19	3·78
February ...	3·12	2·39	2·74	1·96	3·29	2·53	2·48	3·08	1·85	2·85	1·89	2·68
March	2·53	2·88	1·91	1·06	2·47	1·76	1·62	2·20	1·95	2·20	1·74	1·74
April	·35	4·71	·56	5·09	·21	4·36	·49	3·60	·22	3·66	·58	3·83
May	1·43	·31	1·27	·55	2·39	·34	2·36	·33	2·16	·73	1·63	·96
June	·10	1·87	·18	2·93	·28	2·64	1·49	2·11	·64	2·95	·92	2·43
July	·84	3·79	·64	4·98	·47	4·77	2·00	6·31	1·11	4·85	1·17	6·01
August	·65	1·41	1·05	1·53	1·62	1·13	2·44	1·00	1·59	1·42	1·35	1·75
September ...	1·39	7·07	1·80	5·32	2·05	6·49	2·59	4·55	2·23	5·09	2·04	4·37
October	3·25	3·32	5·08	3·69	8·60	4·85	9·71	4·14	9·03	6·26	8·50	6·12
November ...	2·48	3·44	2·71	1·50	3·28	2·14	2·43	2·42	4·30	1·51	3·36	1·79
December ...	3·42	2·69	2·46	2·81	2·31	4·31	2·52	2·86	1·96	3·34	2·42	2·54
Totals	21·62	36·57	22·48	34·38	29·89	39·72	33·12	36·80	30·00	37·79	28·79	38·00

ENGLAND.

Division V.—SOUTH-WESTERN COUNTIES (*continued*).

WILTS (*continued*).		DORSET.						DEVONSHIRE.					
Chippenham, Tytherton.		Blandford.		Dorchester.		Bridport.		Saltram Gardens.		Totness.		Dartmoor Reservoir.	
1 ft. 2 in. 150 ft.		1 ft. 0 in.		0 ft. 6 in. 250 ft.		0 ft. 8 in. 60 ft.		0 ft. 3 in. 95 ft.		1 ft. 0 in. 120 ft.		0 ft. 2 in. 1400 ft.	
1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.
in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
1·85	1·84	1·75	3·07	2·41	3·99	1·74	2·99	3·90	4·10	3·90	4·63	5·47	5·37
1·57	1·06	4·05	2·02	2·90	2·04	2·23	2·26	3·90	2·78	4·57	3·35	5·67	6·23
1·31	1·17	1·77	2·90	2·06	2·58	1·93	1·77	3·00	2·20	3·31	2·46	5·09	3·04
·45	3·23	·29	4·81	·58	5·86	·53	4·96	·50	6·35	·34	5·56	·77	9·99
1·44	1·41	1·21	·84	1·67	1·15	1·44	·99	1·84	·18	2·40	·27	3·76	·54
·56	3·26	·35	2·96	·40	3·17	·76	2·04	·25	2·11	·25	2·65	1·07	4·43
·92	4·06	1·29	4·37	·85	4·11	·66	3·96	1·35	6·86	1·20	6·07	2·77	11·47
1·72	1·26	2·13	1·69	1·60	1·91	·82	·80	3·05	2·50	1·44	1·64	2·58	3·16
1·17	5·68	1·33	4·63	1·96	5·60	·99	4·50	2·00	4·44	2·10	8·62	2·79	8·18
3·52	1·37	5·31	2·89	4·55	5·09	3·52	2·75	4·15	9·11	6·36	5·50	9·27	8·08
1·62	·59	2·60	1·46	2·42	2·02	1·86	1·29	4·20	1·55	3·39	2·39	3·94	1·93
2·01	2·00	3·03	2·59	4·26	2·97	3·84	2·53	3·17	4·70	3·71	5·27	3·77	6·96
18·14	26·93	25·11	34·23	25·66	40·49	20·32	30·84	31·31	46·88	32·97	48·41	46·95	69·38

Division V.—SOUTH-WESTERN COUNTIES (*continued*).

CORNWALL.

Helstone.		Penzance.		Tehidy Park, Redruth.		Truro, Royal Institution.		Bodmin, Castle Street.		Trebarrock House, Wadebridge.		Altarnum	
5 ft. 0 in. 116 ft.		3 ft. 0 in. 94 ft.		0 ft. 6 in. 100 ft.		40 ft 0 in. 76 ft.		2 ft. 6 in. 338 ft.		2 ft 9 in. 303 ft.		0 ft. 10 in. 570 ft.	
1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.	1870	1871.
in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
2·46	4·95	2·77	5·96	4·85	3·30	3·19	4·29	4·16	4·82	3·18	2·08	5·19	5·64
2·77	1·67	3·53	2·24	4·50	3·10	3·61	2·19	5·37	3·66	2·73	1·53	6·44	4·13
2·76	1·14	3·31	1·53	3·50	1·00	2·45	1·57	2·79	1·80	2·02	1·11	3·81	2·99
·20	4·87	·10	4·47	1·45	3·80	·18	4·14	·30	5·64	·22	3·56	·33	6·42
1·44	·90	1·72	·37	·32	1·60	1·72	·55	2·67	·46	1·66	·51	3·77	·71
·66	1·25	·43	1·20	·50	1·90	·32	1·19	·89	2·67	·20	·81	·53	3·17
1·91	5·25	1·76	5·34	1·00	5·15	1·49	5·24	2·10	5·67	1·28	4·77	2·08	7·07
2·12	1·35	2·00	1·94	4·30	2·37	2·25	1·85	3·94	2·50	1·41	1·20	3·47	2·64
1·23	8·27	1·69	7·96	2·00	6·00	1·49	8·50	2·14	8·25	1·68	5·94	2·57	7·84
4·78	5·38	6·02	6·36	6·11	4·90	5·79	5·19	7·56	7·39	4·11	5·24	10·55	8·56
4·69	3·41	5·11	3·15	4·87	3·30	4·13	2·28	4·23	1·77	2·52	1·16	5·21	1·94
2·64	3·16	3·21	4·19	3·60	3·50	2·81	2·86	3·58	4·49	2·15	2·25	3·84	5·13
27·66	41·60	31·65	44·71	37·00	39·92	29·43	39·85	39·73	49·12	23·16	30·16	47·79	56·24

ENGLAND.

	Division V.—South-Western Counties (*continued*).								Division VI.—West Midland Counties.			
	Somerset.								Gloucester.			
Height of Rain-gauge above	Fulland's School, Taunton.		Ilchester.		Sherborne Reservoir, East Harptree.		Batheaston Reservoir.		Clifton.		Cirencester.	
Ground ……	0 ft. 5 in.		2 ft. 0 in.		1 ft. 0 in.		2 ft. 0 in.		0 ft. 6 in.		1 ft. 2 in.	
Sea-level…..	1 ft. 6 in.		40 ft.		338 ft.		226 ft.		192 ft.		420 ft.	
	1870.	1871.	1870.	1871.	1870	1871.	1870	1871.	1870	1871.	1870.	1871.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
January …..	1·44	2·79	1·85	3·19	4·39	2·96	1·85	1·90	2·48	2·12	2·45	1·86
February …	1·95	1·22	2·09	1·45	2·88	2·58	1·65	1·20	1·40	1·56	1·80	1·72
March …..	1·41	1·55	1·06	1·40	2·60	2·59	1·13	1·20	1·58	1·49	1·76	1·65
April ………	·45	3·24	·41	4·34	·87	5·59	·50	2·65	·57	3·76	·68	3·65
May ……..	1·08	·75	·70	·80	2·77	1·02	1·70	1·10	1·54	1·21	1·80	1·70
June ……..	·78	1·93	1·06	1·34	·87	2·48	·70	2·40	·62	1·45	·75	3·00
July ………	·19	2·99	2·76	4·52	2·21	6·21	·87	4·70	1·47	5·11	1·81	4·31
August …..	2·42	1·33	1·67	2·12	1·98	2·15	·95	·80	2·00	1·86	2·74	2·78
September …	1·17	2·65	1·37	4·94	1·52	5·67	·80	4·65	1·77	5·24	1·22	6·70
October ……	3·90	2·95	4·01	2·68	9·64	3·54	4·45	1·65	5·33	2·43	4·54	2·30
November …	3·02	1·35	2·68	·98	2·95	1·48	1·75	·62	2·74	·63	2·26	·40
December …	1·62	2·15	2·09	2·54	2·67	4·25	1·50	2·20	1·93	2·24	2·20	2·33
Totals …..	19·43	24·90	21·75	33·30	35·35	40·52	17·85	25·07	23·43	29·10	24·01	32·40

	Division VI.—West Midland Counties (*continued*).						Division VII.—North Midland Counties.					
	Worcester (*continued*).		Warwick.				Leicester.					
Height of Rain gauge above	Orleton, Tenbury.		Arden House, Henley-in-Arden.		Birmingham.		Wigston.		Thornton Reservoir.		Belvoir Castle.	
Ground ……	0 ft. 9 in.		2 ft. 0 in.		0 ft. 10 in.		0 ft. 9 in.		2 ft. 8 in.		1 ft. 0 in.	
Sea-level……	200 ft. ?		400 ft. ?		340 ft.		220 ft.		420 ft.		237 ft.	
	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
January ……	2·33	2·82	1·27	1·40	2·29	1·49	1·63	·96	1·67	1·07	1·62	1·27
February …	2·50	1·93	1·53	1·43	2·30	1·73	1·64	1·29	1·47	1·28	2·13	1·15
March ……	1·86	1·76	1·47	·98	1·66	1·24	1·10	·94	1·55	·87	1·51	1·04
April ………	·79	2·84	·71	3·17	·91	3·85	·55	2·76	·49	2·86	·89	2·93
May ………	1·40	·97	·97	2·61	1·30	2·16	·71	1·34	·80	2·07	·62	1·14
June ………	·61	3·45	·88	4·30	·78	3·00	·60	3·87	1·06	3·78	·97	2·87
July ………	1·68	3·48	1·18	5·18	1·27	4·55	1·00	4·28	1·16	4·22	1·03	4·29
August ……	2·09	1·29	1·86	·97	1·72	2·18	1·89	·88	1·61	·69	1·14	·56
September …	1·25	7·25	1·33	5·75	·80	6·01	1·60	4·57	1·17	5·47	·54	4·67
October ……	4·87	2·93	3·66	1·17	6·22	1·96	3·45	1·12	4·37	1·61	3·84	1·24
November …	2·78	·80	2·12	·89	2·20	·83	1·38	1·04	1·65	1·10	1·58	1·50
December ..	2·01	1·47	2·16	1·49	2·20	1·62	2·72	1·23	2·33	1·08	3·41	·88
Totals ……	24·17	30·99	19·14	29·34	23·65	30·62	18·27	24·28	19·33	26·10	19·28	23·54

ENGLAND.

Division VI.—West Midland Counties (*continued*).

Gloucester (*continued*).		Hereford.		Shropshire.				Worcester.					
Quedgeley.		Stretton Rectory, Hereford.		Haughton Hall, Shifnall.		Hengoed, Oswestry.		Northwick Park.		West Malvern.		Bromsgrove.	
0 ft. 10 in. 50 ft.		1 ft. 0 in. 198 ft.		3 ft 5 in. 355 ft.		6 ft. 0 in. 470 ft.		1 ft. 6 in.		1 ft. 6 in. 850 ft.		4 ft. 4 in. 273 ft.	
1870.	1871.	1870.	1871	1870	1871.	1870	1871.	1870.	1871.	1870.	1871.	1870.	1871.
in.	in.	in.	in	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
1·73	1·44	1·60	2·53	1·50	1·78	3·33	2·71	1·67	2 05	1 65	2 51	1·38	1·27
1·28	1·70	2 06	1 35	1·76	1·62	2 63	3·60	·81	1 18	2·48	1 06	1·98	1·77
1·57	1·50	1 57	1·28	1 54	·84	3·23	2·14	1 77	1·31	1 69	1·51	1·49	1·01
·75	2·80	·56	2·12	1·09	2·92	1·05	2 75	95	3 33	·66	3 70	·88	2·12
1·44	1·30	1·08	·95	76	1·18	2·31	1 80	1·31	74	·92	1 11	·90	1·95
·68	2·73	·21	3 72	·54	2·31	·54	3 20	74	3·34	1 07	6 33	·99	2·88
1·30	4·34	1·02	3·14	1 04	3·46	·52	4 67	1·24	3 41	1·13	3 50	1 58	4·30
1·13	1 42	·40	1 77	2·92	1·49	1·70	1·94	3 00	1 64	1 74	1·66	2 40	·68
1·62	5·52	·86	6·43	·70	5 27	1·93	5 09	1 82	6 87	1·19	7 53	·84	6·08
2·88	2·25	3 96	3 40	4·47	2·98	7 26	5 09	3 38	1 04	3 99	1 64	4 43	1·89
2 75	·56	1·78	·95	2 75	·89	4·00	1·11	2·54	86	3 00	1·24	1·78	·42
2·02	2·40	1·67	1 53	2 41	1·32	2·71	1·90	2 53	1 86	1 88	1·92	1·96	1·24
19·15	27·96	16·77	29 17	21·48	26·06	31 26	36 00	21·76	27·63	21·40	33·71	20 61	25 61

Division VII.—North Midland Counties (*continued*).

Lincoln.												Nottingham.	
Lincoln.		Market Rasen.		Gainsborough.		Brigg.		Grimsby.		New Holland.		Welbeck.	
3 ft 6 in. 26 ft.		3 ft. 6 in. 100 ft.		3 ft. 6 in. 76 ft.		3 ft 6 in. 16 ft.		15 ft. 0 in. 42 ft.		3 ft 6 in. 18 ft.		4 ft. 0 in. 80 ft	
1870.	1871.	1870	1871.	1870.	1871	1870	1871.	1870.	1871.	1870.	1871.	1870.	1871.
in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
·94	·42	1·35	·70	1·30	·37	1·10	·66	·79	1·23	1·12	·78	1·45	·98
·39	1·23	1 72	1·95	1·02	1·04	2·41	1·79	1 23	1·44	1 63	1·89	1·62	1·41
1·20	·50	1·54	·88	61	·31	2·17	·65	1·53	·77	1·99	·81	2·20	·93
·48	2·90	·68	3 06	·55	4·77	·44	2 91	·73	2·74	·43	3·07	·66	3·05
·82	·63	·63	1·25	·76	·44	·59	1 75	·59	1·55	·94	1·03	·95	1·73
1·75	2·21	1·83	3·40	1·38	3·35	2·48	2·57	1·80	2·11	3·33	3·61	1·89	3·71
·90	2·98	·90	3·00	1·05	2·94	68	2·73	·30	3·26	·76	3·05	·60	3·21
1·19	·55	1·87	1 03	1·56	1·04	1·74	1 76	1·68	1·37	1·64	1·07	1·13	·98
1·00	4·83	1·21	4·06	1·22	4·68	1·46	5·87	1·03	4 06	1·13	5·07	1·21	5·31
3·92	·70	9·58	·43	5·15	1·16	6·73	1·03	5·37	1·35	6·15	1·02	5·58	1·78
1·56	1·20	1·91	1·77	·53	1·09	1·42	1·16	2·15	1·39	1·12	1·85	1·81	·82
2·14	·97	1·99	1·62	1·31	1·18	2·84	1 29	2·90	1·41	3·43	1·31	2·48	1·57
16·29	19·12	25·26	23·15	16·44	22·37	24·06	24·17	20·10	22·68	23 67	24·56	21·58	25·48

ENGLAND.

	Division VII.—North Midland Counties (continued).								Div. VIII.—North-Western Counties.			
	Derby.								Cheshire.			
Height of Rain-gauge above	Derby.		Chesterfield.		Comb's Moss.		Chapel-en-le-Frith.		Macclesfield.		Cholmondelly Castle, Nantwich.	
Ground	6 ft. 0 in.		3 ft. 6 in.		3 ft. 6 in.		3 ft. 6 in.		3 ft. 6 in.		1 ft. 6 in.	
Sea-level......	180 ft.		248 ft.		1669 ft.		965 ft.		539 ft.		42 ft.	
	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
January......	1·43	·82	1·99	1·12	3·92	1·59	3·94	1·55	1·64	·77	1·73	1·55
February ...	1·09	1·51	1·84	1·94	3·08	3·23	2·42	3·34	·89	1·95	1·22	2·54
March	1·47	1·15	2·25	1·18	3·95	1·75	3·24	1·46	1·85	·76	2·52	1·58
April	·75	3·72	·25	2·25	1·85	6·29	1·57	4·30	1·78	2·84	1·72	2·68
May	·72	1·68	1·22	1·40	1·97	4·40	2·03	3·23	·73	2·86	1·31	1·52
June	1·23	4·16	·98	4·23	1·81	4·00	1·69	4·35	1·93	3·97	1·70	3·18
July	·79	4·68	·83	3·39	2·83	4·36	1·78	4·53	2·02	5·78	1·50	5·49
August	1·15	1·35	·66	1·19	1·81	2·94	1·57	2·45	2·06	1·93	1·54	1·29
September...	1·13	4·92	1·04	4·80	3·26	6·67	3·11	4·75	2·62	4·58	2·21	4·90
October	4·91	2·37	5·58	2·91	9·92	4·93	11·11	6·03	5·67	5·92	5·44	3·97
November ...	1·99	1·05	1·95	·85	2·76	1·93	2·82	1·73	·84	2·47	2·46	1·34
December ...	2·07	1·29	2·41	1·30	3·08	3·53	2·62	2·83	1·80	2·51	2·86	1·69
Totals	18·73	28·70	21·00	26·56	40·24	46·12	37·90	41·55	23·83	36·34	26·21	31·73

	Division VIII.—North-Western Counties (continued).				Division IX.—Yorkshire.							
	Lancashire (continued).				York.—West Riding.							
Height of Rain-gauge above	Caton, Lancaster.		Holker, Cartmel.		Broomhall Park, Sheffield.		Redmires, Sheffield.		Tickhill.		Penistone.	
Ground	1 ft. 6 in.		4 ft. 8 in.		2 ft. 0 in.		4 ft. 0 in.		2 ft. 0 in.		3 ft. 6 in.	
Sea-level......	120 ft.		155 ft.		340 ft.		1100 ft.		61 ft.		717 ft.	
	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871	1870.	1871.	1870.	1871.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
January......	3·96	1·95	4·34	2·13	2·82	1·21	3·63	1·25	1·21	·96	3·52	1·74
February ..	2·64	4·45	2·16	4·37	1·85	2·10	2·87	3·11	1·37	1·54	2·15	2·76
March	2·56	1·89	2·28	2·23	2·19	1·26	2·71	1·38	2·13	·83	2·21	1·42
April	1·76	2·97	1·60	3·79	·66	3·12	1·19	4·74	·47	2·77	·88	3·07
May	2·51	1·78	2·79	1·81	·94	1·42	1·29	1·77	·58	1·85	1·62	1·31
June	2·12	2·44	1·88	2·25	1·27	4·63	1·69	3·81	2·08	4·23	1·93	4·42
July	2·02	5·97	1·56	4·93	·97	3·08	1·18	3·42	·78	3·63	·55	2·63
August	2·27	1·95	1·97	3·19	·86	1·65	1·47	2·06	·97	1·59	·98	1·83
September...	3·39	3·96	3·65	3·78	1·63	6·40	2·38	6·09	·68	5·23	2·66	6·34
October	9·86	6·14	11·30	6·36	7·87	2·74	9·67	3·30	5·71	1·51	8·66	3·13
November ...	3·02	1·31	3·07	2·36	1·92	1·52	2·22	1·86	1·73	·89	2·26	1·51
December ...	3·56	4·28	2·64	5·21	3·03	1·50	3·16	2·03	2·97	1·41	2·14	1·39
Totals	39·67	39·59	39·24	42·41	26·01	30·63	33·46	34·82	20·68	26·44	29·56	31·55

ENGLAND.

Division VIII.—North-Western Counties (*continued*).

Lancashire.

Manchester.		Waterhouses.		Bolton-le-Moors.		Rufford, Ormskirk.		Howick House, Preston.		South Shore, Blackpool.		Stonyhurst.	
2 ft. 7 in. 106 ft.		3 ft. 6 in. 345 ft.		3 ft. 6 in. 283 ft.		0 ft. 8 in. 38 ft.		0 ft. 6 in. 73 ft.		1 ft. 8 in. 29 ft.		0 ft. 8 in. 376 ft.	
1870.	1871.	1870	1871	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.
in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
3·13		3·25	1·22	3·95	1·70	2·45	1·32	3·30	1·50	3·30	1·20	4·11	1·73
·85	2·73	·95	5·31	1·41	4·59	1·02	2·82	1·20	3·20	1·72	2·88	1·61	4·55
2·38	1·56	2·02	1·26	3·31	2·09	2·09	1·12	2·30	2·00	2·40	1·45	2·92	1·97
2·22	3·52	1·80	4·39	2·46	3·78	1·44	2·56	1·60	2·40	1·10	2·20	2·64	3·60
·75	2·07	1·13	2·13	1·91	1·86	1·62	1·62	1·50	1·70	1·45	1·45	1·95	1·80
1·79	2·66	1·47	4·72	4·01	3·57	1·58	2·05	1·60	2·25	1·15	1·75	2·23	3·36
·81	3·55	2·00	4·32	1·13	4·82	·55	4·94	·65	4·80	1·10	4·43	2·27	8·03
1·65	1·60	2·24	1·71	2·51	1·71	2·12	1·09	3·10	2·00	1·23	1·38	2·87	2·07
2·66	3·82	2·26	4·93	3·78	5·30	2·72	3·62	2·90	2·90	3·00	2·90	3·99	4·20
8·36	4·51	11·33	4·75	11·54	6·11	8·80	6·90	10·62	6·90	9·60	6·15	13·36	6·58
2·42	1·41	3·05	1·57	3·89	1·76	3·14	1·40	3·00	1·40	2·70	1·50	3·52	2·03
2·53	2·50	2·14	2·60	3·57	3·64	2·31	2·51	2·40	3·20	2·66	2·65	4·09	3·89
29·55	33·23	33·64	36·91	43·47	40·93	29·84	31·95	34·17	34·25	31·41	29·94	45·56	43·91

Division IX.—Yorkshire (*continued*).

York.—West Riding (*continued*).

Saddleworth.		Longwood, Huddersfield.		Ackworth, Pontefract.		Well Head, Halifax.		Ovenden Moor, Halifax.		Eccup, Leeds.		York.	
5 ft. 0 in. 640 ft.		4 ft. 6 in. 650 ft.		0 ft. 3 in. 135 ft.		0 ft. 11 in. 487 ft.		0 ft. 10 in. 1375 ft.		0 ft. 9 in. 340 ft.		0 ft. 6 in. 50 ft.	
1870.	1871	1870.	1871	1870	1871	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871
in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
3·28	2·07	3·33	·92	1·42	·66	3·36	1·00	3·80	1·50	2·26	·77	1·68	·70
1·86	2·35	1·56	2·34	1·47	1·64	1·77	2·60	2·10	3·70	1·07	2·84	1·88	2·51
2·59	2·14	2·54	·96	1·89	·56	2·20	1·18	2·40	1·10	1·71	1·09	1·80	1·21
2·97	3·59	·96	2·89	·42	2·75	·80	3·88	1·70	5·20	·83	3·25	·66	2·76
1·65	2·12	1·17	1·39	·75	1·50	1·43	1·90	2·00	2·20	1·36	·97	1·08	1·31
2·39	4·03	1·18	2·96	1·73	5·13	1·78	3·28	1·80	3·50	1·54	3·70	2·81	3·72
1·13	4·67	·47	1·56	·68	2·71	·55	2·77	1·00	5·30	·80	3·58	·51	2·80
2·21	1·97	·99	·90	1·33	1·81	1·30	1·28	1·50	1·70	1·93	1·19	1·58	1·03
4·13	5·24	1·94	2·73	·93	5·80	1·76	4·73	2·00	4·80	1·05	6·70	1·18	6·60
9·97	5·07	5·47	1·43	5·53	1·69	8·96	2·98	10·80	3·90	7·26	3·25	6·10	2·67
2·88	·86	2·78	·31	1·75	·96	2·74	·87	3·20	1·00	2·19	1·04	1·93	1·25
3·05	3·62	1·75	·65	2·93	·99	2·94	1·43	3·00	2·80	3·39	1·44	3·16	2·12
38·11	37·73	24·14	19·04	20·83	26·20	29·59	27·90	35·30	36·70	26·29	29·82	24·37	28·68

ENGLAND.

Division IX.—Yorkshire (*continued*).

	York.—West Riding (*continued*).				York.—East Riding.				York.—North Riding.			
Height of Rain-gauge above	Harrogate.		Arncliffe.		Beverley Road, Hull.		Warter, Pocklington.		Malton.		Beadlam Grange.	
Ground ...... Sea-level......	0 ft. 6 in. 380 ft.		2 ft. 9 in. 750 ft.		3 ft. 10 in. 11 ft.		1 ft. 10 in. 230 ft.		1 ft. 0 in. 75 ft.		0 ft 6 in. 192 ft.	
	1870.	1871	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
January	2·59	·79	6·24	2·65	1·19	1·04	1·43	·80	1·88	1·00	2·13	1·06
February ...	2·72	2·98	5·10	6 64	2·09	1·79	1·99	2·44	2·33	2·34	2·49	2·48
March	2·16	1·55	3·06	4·67	2·28	·90	1·62	1·20	1·60	·75	·94	·93
April	·79	3·14	2·46	3·95	·52	3·14	·62	3·52	·67	2·80	·57	3·52
May	1·33	1·04	2·48	2·03	·81	1·21	1·40	1·69	1·13	1·79	1·64	1·34
June	1·48	4·24	3·52	2·77	3·17	2·99	2·83	2·95	2·60	2·98	2·40	4·05
July	·69	2·38	·59	9·22	·71	3·74	·36	4·17	·27	3·82	·32	3·98
August	1·35	1·86	2·24	2·86	1·76	·95	2·04	·94	1·93	87	2·23	1·24
September ...	·88	6·63	2·90	6 04	1·52	4·77	1·80	7·81	1·10	5·91	1·31	5·15
October	7·56	3·24	13·38	5·13	5·79	1·21	5·71	1·80	5·98	2·13	6·01	2·63
November ...	2·85	1·29	3·94	2·13	1·62	2·23	2·32	1·95	2·82	1·77	4·20	1·78
December ..	3·74	2·08	4·23	4·64	4·35	1·71	4·41	2·26	4·01	1·60	4·21	2·16
Totals	28·14	31·22	50·14	52 73	25·81	25·68	26·53	31·53	26·32	27·76	28·45	30·32

Division X.—Northern Counties (*continued*).

	Northumberland (*continued*).				Cumberland.							
Height of Rain-gauge above	Haltwhistle.		Lilburn Tower.		Bootle.		Seathwaite.		Whinfell Hall, Cockermouth.		Post Office, Keswick.	
Ground ...... Sea-level......	0 ft. 9 in. 380 ft.		6 ft. 0 in. 300 ft.		1 ft. 0 in. 87 ft.		1 ft. 0 in. 422 ft.		2 ft. 0 in. 265 ft.		1 ft. 0 in. 270 ft.	
	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
January	3·22	2·33	1 87	·31	3·87	2·53	13·48	11·95	5·82	4·37	3·35	4·93
February ...	2·38	2·17	2·76	2·43	2·88	5·90	13 67	15·99	5·07	4·71	5·96	4·70
March	1·29	1·63	1·19	·85	2·67	2 52	9·51	10·26	2·56	3·33	2·36	4·50
April	·83	3·45	·62	3·62	1·95	3·62	6·50	6 36	2·85	2·43	2·71	2·57
May	1·50	1·27	1 62	·90	2·73	1·36	13·49	2·63	5·55	1·24	5·56	·67
June	2·49	2·27	1 26	2·84	1·64	1·65	6·41	2·82	1·52	1·75	4·10	1·73
July	1·46	4·63	·63	2·54	1·46	3·12	1 75	12·57	·95	3·38	·98	4·49
August	1·35	2·34	1·92	1·24	1·63	2·15	2·68	9·10	2·03	3·82	3·33	3·67
September ...	2·32	4·40	1·05	3·67	3·26	2·43	12·70	5·53	5·22	2·60	6·82	2·20
October	5·14	2·78	3·43	2·73	8·33	6·83	24·17	6 24	11·27	4·18	12·44	4·48
November ...	1·80	1·81	2·44	2·71	3·42	4·44	8·03	9·91	3·58	2·78	4·20	1·84
December ...	3·12	3·93	4·48	1·60	3·42	4·36	7·21	21·79	2·44	7·11	2·62	8·13
Totals	26·90	33·01	23·27	25·44	37·26	40·91	119·60	115·15	48·86	41·70	54·43	43·91

ENGLAND.

Division IX.—YORKSHIRE (*continued*).				Division X.—NORTHERN COUNTIES.									
YORK.—NORTH RIDING (*continued*).				DURHAM.						NORTHUMBERLAND.			
Thirsk.		Scarborough.		Darlington, Southend Gardens.		Ushaw, Durham.		Stanhope Castle.		Bywell.		North Shields.	
2 ft. 6 in. 114 ft.		1 ft. 0 in. 102 ft.		1 ft. 0 in. 140 ft.		0 ft. 10 in. 600 ft.		4 ft. 0 in. 670 ft.		0 ft. 6 in. 87 ft.		1 ft. 0 in. 124 ft.	
1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.
in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
1·71	·59	1·60	1·07	1·38	·67	2·05	1·17	4·59	2·60	1·53	1·50	1·60	1·13
1·94	2·50	2·20	1·71	1·09	1·29	1·69	1·78	1·41	1·51	1·89	2·46	1·95	1·97
1·37	·97	1·40	·62	1·20	·76	1·40	·93	2·50	1·05	1·16	1·20	1·21	·69
·55	1·92	·85	3·24	·47	2·02	·62	3·12	1·50	3·05	·64	3·40	·78	3·79
·34	1·16	1·10	1·44	·70	1·32	1·35	1·89	·10	1·50	·80	·90	1·40	1·59
3·20	4·15	2·84	2·49	1·60	3·21	1·54	3·41	1·17	3·00	1·61	3·60	2·44	2·54
·42	3·57	·56	3·75	·44	2·89	·79	3·35	·60	3·77	·71	4·40	·55	3·79
2·18	·69	2·31	·79	1·79	1·08	2·29	1·49	3·01	1·05	2·17	·77	2·12	·96
1·04	4·20	·81	5·77	·55	3·30	·80	5·03	1·09	6·40	1·52	6·48	·99	4·01
5·23	2·48	5·56	1·99	4·54	1·95	5·08	2·35	8·08	3·39	5·18	3·30	3·47	1·97
3·15	1·21	3·17	3·04	1·67	1·64	2·46	1·56	2·70	2·00	2·44	3·28	3·50	1·84
3·40	1·70	6·00	2·02	2·54	·97	4·79	1·80	4·77	3·50	6·19	2·24	5·22	1·90
24·53	25·14	28·40	27·93	17·97	21·10	24·86	27·88	31·52	32·82	25·84	33·53	25·22	26·18

Division X.—NORTHERN COUNTIES (*continued*).													
CUMBERLAND (*continued*).						WESTMORELAND.							
Cockermouth		Mire House, Bassenthwaite		Sealeby Hall.		Kendal.		Kirkby Stephen		Appleby.		Great Strickland, Penrith.	
0 ft. 6 in. 158 ft.		0 ft. 7 in. 310 ft.		1 ft. 1 in. 112 ft.?		1 ft. 6 in. 146 ft.		1 ft. 0 in. 571 ft.		1 ft. 0 in. 442 ft.		1 ft. 6 in. 650 ft.	
1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.
in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
4·41	3·98	5·68	4·56	3·81	1·72	5·67	2·85	4·09	2·34	3·28	2·07	4·14	3·46
3·56	3·52	5·18	3·89	2·27	2·54	3·29	5·04	3·06	3·26	3·07	2·88	4·19	3·65
2·35	2·94	3·44	3·57	1·06	1·33	2·85	2·66	1·65	2·34	1·18	2·30	1·29	6·16
2·11	2·50	2·34	2·29	1·30	3·23	2·06	3·26	1·18	2·68	·75	1·74	1·49	2·26
4·02	·97	4·30	1·21	2·61	1·16	4·87	1·83	2·24	1·00	2·35	1·23	2·70	1·35
1·97	1·75	1·40	1·63	2·35	2·94	1·58	1·98	1·52	3·57	1·33	2·79	1·56	2·73
1·05	2·92	1·08	2·82	1·06	3·92	1·25	7·67	2·46	6·50	·76	4·77	·71	3·35
2·85	3·31	3·39	4·81	1·49	2·27	1·74	6·99	1·81	2·56	2·31	2·72	2·15	2·59
4·32	2·23	4·71	2·81	2·28	2·07	3·09	3·94	2·33	3·64	2·48	3·20	3·44	3·29
9·56	3·81	11·13	3·65	5·00	3·83	10·25	6·65	7·36	4·30	5·18	3·72	8·12	4·35
3·52	2·64	3·53	2·22	2·25	1·61	4·05	1·56	3·20	1·19	2·39	·93	2·62	1·24
2·00	6·32	2·79	6·66	1·41	3·75	2·39	5·82	2·87	3·58	2·23	3·45	2·90	3·69
41·72	36·89	48·97	40·12	26·89	30·37	43·09	50·25	33·77	36·96	27·31	31·80	35·31	38·12

WALES.

Division XI.—Monmouth, Wales, and the Islands.

Height of Rain-gauge above Ground …… Sea-level……	Monmouth.				Glamorgan.		Carmarthen.		Pembroke.		Brecknock.	
	Llanfrechfa, Newport.		Abergavenny.		Swansea.		Carmarthen Gaol.		Haverford-west.		Brecknock	
	4 ft. 0 in. 360 ft.		1 ft 0 in. 220 ft.		14 ft. 9 in. 40 ft.		0 ft. 6 in. 92 ft.		1 ft. 0 in. 95 ft.		2 ft. 0 in. 437 ft.	
	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.
	in.	in.	in.	in.	in.	in	in.	in.	in.	in.	in.	in.
January ...	4·07	2·39	2·96	3·05	2·44	3·65	4·17	4·80	4·28	6·05	5·22	7·14
February ...	4·27	3·37	4·24	2·63	2·49	2·40	5·55	4·02	3·92	3·31	8·38	3·42
March	1·90	2·53	1·96	1·96	2·28	1·73	3·99	3·06	3·88	2·24	·33	3·75
April	·33	6·15	·35	3·74	·23	4·10	·81	4·69	·71	4·44	·50	4·76
May	2·62	1·00	2·08	·87	1·77	·86	3·24	·89	3·26	·53	3·03	·91
June	·22	1·91	·17	2·43	·33	·78	·80	2·99	1·18	1·50	·22	2·28
July	3·31	5·20	1·92	4·54	1·83	5·34	1·74	7·17	2·21	4·97	1·73	3·30
August	3·85	4·60	1·39	2·46	1·87	1·70	2·68	3·28	2·70	2·18	2·75	4·81
September..	2·79	8·32	1·50	6·62	1·91	2·99	2·80	6·66	2·75	7·48	2·89	5·25
October	8·25	3·76	6·22	4·93	6·26	5·20	9·36	7·38	8·52	7·64	10·20	5·99
November ..	4·64	1·21	4·68	·85	3·52	1·28	5·64	2·09	3·98	1·81	6·18	1·05
December ..	2·54	4·67	2·43	2·72	1·01	2·66	1·85	5·09	2·62	4·58	2·14	4·05
Totals	38·79	45·11	29·90	36·80	25·94	32·69	42·63	52·12	40·01	46·73	43·57	46·71

Division XI.—Monmouth, Wales, and the Islands (*continued*).

Height of Rain-gauge above Ground …… Sea-level……	Carnarvon (*continued*).						Isle of Man.				Guernsey.	
	Plas Brereton.		Llanfairfe-chan.		Llandudno.		Douglas Head.		Point of Ayr.		Guernsey.	
	1 ft. 0 in. 25 ft.		0 ft. 8 in. 150 ft.		0 ft. 6 in. 99 ft.		0 ft. 6 in. ……… ..		3 ft. 4 in. 27 ft. ?		12 ft. 0 in. 204 ft.	
	1870.	1871.	1870.	1871.	1870	1871.	1870.	1871.	1870.	1871.	1870.	1871
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
January ...	3·74	3·74	3·85	3·96	2·80	1·87	3·43	3·37	2·30	2·05	3·45	5·91
February ...	1·93	3·03	2·38	3·05	1·53	2·02	2·89	3·28	2·55	2·94	1·88	2·05
March	2·61	2·24	3·15	1·85	1·88	·77	2·18	1·25	1·60	1·15	2·55	1·13
April	2·03	2·19	2·21	3·09	2·08	2·57	·33	4·25	·49	2·58	·76	3·45
May	1·49	·75	1·72	·83	·73	1·19	1·08	·45	1·47	·61	1·65	·73
June	1·30	1·84	1·16	1·61	1·06	2·27	·63	1·12	·90	1·18	·21	2·51
July	·83	4·65	·89	3·29	·54	3·33	·55	1·70	·75	1·73	1·26	3·97
August	1·95	1·84	1·61	1·37	1·44	1·24	1·65	3·72	1·28	2·17	1·01	1·43
September ...	2·57	3·14	2·55	4·41	2·18	3·59	1·42	1·21	2·31	·88	·66	5·31
October	8·27	5·71	9·34	6·19	7·04	6·17	5·65	6·51	5·82	3·51	5·35	5·55
November ...	6·52	1·38	4·48	1·85	2·94	3·24	2·20	4·55	2·47	2·27	3·70	1·62
December ..	3·35	3·91	3·39	2·25	3·21	2·30	1·63	5·00	1·95	3·14	2·57	2·60
Totals	36·59	34·42	36·73	33·75	27·43	30·56	23·64	36·41	23·89	24·21	25·05	36·26

WALES.

Division XI.—Monmouth, Wales, and the Islands (*continued*).

Montgomery.		Cardigan.		Radnor.		Merioneth.		Flint.				Carnarvon.	
Carno.		Aberystwith.		Rhayader.		Dolgelly, Brithdin.		Maes-y-dre.		Hawarden.		Beddgelert.	
1 ft. 0 in. 550 ft.		1 ft. 0 in. 42 ft.		2 ft. 0 in. 880 ft.		1 ft. 6 in. 500 ft.		5 ft. 0 in. 400 ft.		0 ft. 4 in. 270 ft.		3 ft. 0 in. 264 ft.	
1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.
in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
3·70	3·60	2·67	3·95	4·49	3·19	4·74	6·43	1·88	·86	2·32	2·29	12·30	8·17
2·60	2·40	2·48	2·47	3·92	4·88	7·62	7·90	·90	1·73	1·33	2·07	4·74	17·38
2·90	2·90	2·36	2·13	2·79	1·48	5·68	4·60	2·03	1·14	1·85	1·25	7·79	8·80
2·30	4·30	2·27	3·12	·89	6·15	3·88	5·76	·61	2·08	1·30	2·13	6·08	9·11
2·10	1·20	1·87	·75	2·73	·98	4·06	1·17	1·34	1·10	1·02	1·56	8·00	2·70
2·00	2·80	1·52	2·74	·90	3·73	2·65	2·01	1·31	2·67	·78	2·80	4·82	4·35
2·40	5·50	3·29	5·50	1·98	6·04	2·05	7·47	·37	3·54	·58	3·23	2·58	16·33
2·10	2·90	3·42	2·96	2·00	2·97	3·67	3·53	1·41	1·05	2·32	1·02	4·67	5·69
3·50	5·70	3·32	2·76	3·11	4·15	4·45	4·35	1·76	2·97	1·90	4·29	8·40	5·96
11·20	4·80	11·53	5·11	12·23	6·89	16·72	8·82	5·48	4·53	4·41	4·38	22·92	14·09
6·30	1·80	6·40	3·01	3·85	1·24	8·82	2·30	3·56	1·43	2·60	1·61	10·58	5·38
3·20	2·40	3·43	2·26	2·46	2·23	6·78	6·33	2·20	1·53	2·88	1·59	8·70	12·93
44·30	40·30	44·56	36·76	41·35	43·93	71·72	60·67	22·85	24·63	23·29	28·22	101·58	110·89

Div. XI.—Monmouth, Wales, &c. (*continued*).				SCOTLAND. Division XII.—Southern Counties.									
Sark.		Alderney.		Wigtown.		Kirkcudbright.						Dumfries.	
Sark.		Alderney.		South Cairn.		Little Ross		Carsphairn.		Cargen.		Drumlanrig.	
1 ft. 0 in. 340 ft.		10 ft. 0 in. 48 ft.		1 ft. 1 in. 209 ft.		3 ft. 3 in. 130 ft.		3 ft. 10 in. 574 ft.		0 ft. 4 in. 80 ft.		0 ft. 6 in. 191 ft.	
1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.
in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
2·88	4·46	1·56	3·38	8·35	5·05	2·40	1·46	6·02	4·6[illegible]	5·29	3·92	4·40	5·00
1·65	1·57	1·41	2·75	8·85	8·95	2·13	4·30	7·30	5·71	5·20	5·90	6·20	5·00
2·15	·98	1·72	·69	3·00	2·85	1·14	1·01	2·20	5·18	1·29	3·47	1·60	·90
·66	3·20	·48	2·42	5·65	8·20	·60	3·30	2·71	5·16	1·61	4·33	2·20	3·20
1·43	·63	1·15	·42	4·85	2·05	1·67	·50	4·15	1·29	4·68	1·00	3·90	·90
·18	2·65	·06	1·96	3·95	2·40	1·77	1·16	1·84	5·19	1·40	2·18	1·70	3·20
1·12	3·83	1·30	2·70	4·05	5·25	·77	1·85	1·31	4·58	1·16	4·83	2·00	4·80
1·51	1·02	1·45	2·10	2·90	3·10	1·31	3·37	1·75	4·39	2·14	3·02	·11	3·80
1·69	4·97	·99	4·35	6·30	2·80	2·12	1·26	5·31	2·24	4·06	2·60	4·40	1·20
5·20	4·12	4·20	3·52	8·10	4·80	4·41	3·53	12·19	5·50	8·56	4·00	7·50	4·70
2·62	1·32	1·78	1·47	4·05	7·15	2·58	2·83	3·35	4·83	2·32	3·40	2·80	2·90
3·24	2·57	4·95	1·42	2·20	3·55	2·05	3·03	3·20	8·67	2·26	5·89	2·00	6·30
24·33	31·32	21·05	27·18	62·25	56·15	22·95	27·60	51·33	57·41	39·97	44·54	38·81	41·90

SCOTLAND.

Div. XII.—Southern Counties (*continued*).			Division XIII.—South-Eastern Counties.									
Dumfries (*continued*).			Roxburgh.		Selkirk.		Peebles.		Berwick.		Haddington.	
	Wanlockhead.		Silverbut Hall, Hawick.		Bowhill.		N. Esk Reservoir, Penicuick.		Thirlestane.		East Linton.	
Height of Rain-gauge above Ground …… Sea-level……	0 ft. 4 in. 1330 ft.		4 ft. 0 in. 512 ft.		11 ft. 0 in. 537 ft.		0 ft. 6 in. 1150 ft.		0 ft. 3 in. 558 ft.		0 ft. 3 in. 90 ft.	
	1870.	1871.	1870.	1871.	1870	1871.	1870.	1871.	1870.	1871.	1870.	1871.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
January …	5·66	6·10	2·58	1·81	3·34	2·03	2·40	2·55	2·40	1·60	·79	1·13
February …	6·94	8·84	2·38	1·91	2·89	3·50	2·95	3·05	1·60	4·10	2·94	2·26
March ……	2·66	6·26	1·03	2·00	1·12	2·13	1·40	1·90	1·00	1·50	1·13	·38
April ………	3·07	4·28	·96	4·08	·80	3·89	·70	4·50	·05	3·80	·22	4·69
May ………	5·36	1·05	1·93	1·06	2·63	1·05	1·00	1·10	1·80	·90	·57	·85
June ……..	2·02	2·02	1·86	2·87	2·10	3·37	2·90	2·20	2·35	3·10	1·68	3·22
July ………	1·89	5·84	2·04	3·02	1·25	3·16	1·20	3·15	·90	3·50	·93	2·27
August ……	1·90	5·59	1·54	2·10	1·43	2·74	1·00	3·55	1·80	1·50	1·69	1·27
September …	4·59	3·35	1·97	1·95	2·10	1·73	2·45	2·25	1·60	3·00	2·26	2·43
October ……	7·95	4·67	3·35	2·45	3·79	2·83	3·65	2·15	3·50	2·70	2·45	2·55
November ..	4·50	2·53	1·71	2·09	1·08	1·92	1·15	4·60	1·50	3·70	·80	3·16
December …	2·77	9·21	1·64	3·16	2·53	2·8	2·25	3·30	3·90	2·20	3·84	1·41
Totals …..	49·31	59·74	22·99	28·50	25·06	31·23	23·65	34·30	22·40	31·60	19·30	25·62

Division XIV.—South-Western Counties (*continued*).												
Lanark (*continued*).			Ayr.						Renfrew.			
	Hill End House, Shotts.		Girvan.		Auchendrane.		Mansfield, Largs.		Nether Place, Mearns.		Greenock.	
Height of Rain-gauge above Ground ….. Sea-level…..	7 ft. 0 in. 620 ft.		1 ft. 0 in. 187 ft.		2 ft. 3 in. 96 ft.		0 ft. 6 in. 30 ft.		0 ft. 6 in. 360 ft		0 ft. 6 in. 64 ft.	
	1870.	1871.	1870.	1871	1870	1871.	1870.	1871.	1870.	1871.	1870	1871.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
January……	2·52	2·54	4·15	4·36	3·54	3·99	5·80	3·30	2·00	5·00	7·13	5·90
February …	1·55	3·83	5·14	7·14	2·45	4·53	4·90	7·50	3·75	5·75	5·64	8·65
March ……	·88	2·22	2·06	4·14	1·43	4·04	1·00	4·50	1·50	4·50	1·30	6·11
April………	1·24	2·12	2·29	2·97	2·11	3·34	1·90	3·30	2·25	4·25	2·55	5·14
May ………	2·35	·32	2·30	1·02	4·15	·85	5·00	·70	5·13	1·25	5·64	1·60
June …….	2·49	·46	3·88	2·57	2·40	2·13	1·90	1·90	2·06	2·00	1·91	3·73
July ………	2·53	4·98	1·81	2·84	2·02	3·55	2·60	3·40	2·12	4·50	2·51	3·51
August ……	·79	3·24	2·06	4·45	2·06	5·15	2·30	3·40	2·25	6·50	1·77	4·40
September..	2·66	1·76	3·70	2·52	3·87	2·08	3·90	2·60	4·37		4·45	2·32
October……	3·31	2·16	12·29	4·03	4·99	2·65	5·60	3·80	5·38	3·50	7·15	6·62
November …	1·89	1·23	3·28	6·03	2·15	2·80	2·80	4·00	2·50	4·25	2·33	4·82
December …	1·92	1·67	2·85	5·76	2·05	5·06	3·10	4·40	3·38	6·38	4·62	9·51
Totals ……	24·13	26·53	45·81	47·83	33·22	40·17	40·80	42·80	36·69	47·88	47·00	62·31

SCOTLAND.

Division XIII.—South-Eastern Counties (*continued*).						Division XIV.—South-Western Counties.							
Edinburgh.						Lanark.							
Glencorse.		Inveresk.		Charlotte-sq., Edinburgh.		Newmains, Douglas.		Auchinraith, Hamilton.		Glasgow Observatory.		Baillieston.	
0 ft. 6 in. 787 ft.		2 ft. 0 in. 60 ft.		0 ft. 6 in. 230 ft.		0 ft. 4 in. 783 ft.		4 ft. 9 in. 150 ft.		0 ft. 1 in. 180 ft.		0 ft. 3 in. 230 ft.	
1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.
in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
2·40	2·70	1·67	1·26	1·68	1·25	3·48	4·49	2·89	2·65	4·18	3·38	5·44	3·77
4·05	2·90	2·05	1·79	5·70	2·41	5·66	3·27	2·05	2·75	6·33	4·86	2·31	4·63
2·25	1·85	1·00	·94	1·11	1·07	1·08	4·54	·63	1·94	·93	3·05	1·09	3·26
·75	4·60	·27	5·11	·43	4·55	1·47	3·04	·80	3·02	1·46	4·42	1·29	5·52
1·60	·70	·77	·71	1·31	·83	3·17	·61	2·18	·78	3·20	1·12	3·72	1·43
3·25	2·35	1·80	2·98	2·25	1·90	2·75	3·29	1·45	1·75	1·84	2·72	2·49	3·16
1·95	3·10	1·26	3·90	1·65	2·80	1·75	4·99	1·67	4·05	2·52	4·51	3·71	5·82
1·65	2·65	·93	2·14	1·29	2·56	2·48	4·29	1·03	6·55	1·76	3·66	1·25	4·82
2·50	3·05	1·77	3·23	1·84	2·55	4·09	1·80	2·32	1·43	3·71	1·60	4·37	2·12
3·50	2·55	1·73	2·42	1·76	2·45	4·75	4·28	2·95	1·97	4·61	3·10	4·77	3·00
1·40	4·70	·85	4·21	·69	2·87	2·76	2·11	1·95	2·40	1·84	3·27	2·53	3·57
2·40	3·20	2·40	1·73	2·40	1·63	1·78	5·38	1·84	2·73	2·87	4·85	3·20	4·59
27·70	34·35	16·50	30·42	22·11	26·87	35·22	42·09	21·76	32·02	35·25	40·54	36·17	45·69

Division XV.—West Midland Counties.													
Dumbarton.				Stirling.		Bute.		Argyll.					
Balloch Castle.		Arddarroch, Loch Long.		Polmaise Garden.		Pladda.		Devaar, Campbelltown		Rhinns of Islay.		Ellabus, Islay.	
0 ft. 4 in. 91 ft.		0 ft. 10 in. 80 ft.		0 ft. 2 in. 12 ft.		3 ft. 3 in. 55 ft.		3 ft. 4 in. 75 ft.		3 ft. 0 in. 74 ft.		1 ft. 0 in. 67 ft.	
1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.
in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
5·40	4·23	7·19	7·52	3·80	3·60	2·89	4·11	3·70	6·45	1·94	2·78	3·39	4·16
5·00	6·81	7·51	7·93	3·30	4·60	2·38	6·76	5·08	7·16	1·76	3·70	3·30	5·16
1·20	3·90	2·30	6·67	·60	2·80	·75	1·92	1·81	3·41	1·22	2·58	1·25	3·79
2·51	5·11	3·06	6·56	·60	4·30	1·31	3·76	1·79	4·47	1·68	3·37	2·58	3·95
3·95	1·25	6·13	2·02	2·70	1·30	2·75	·37	4·28	·80	1·84	·87	3·09	1·13
1·77	2·03	3·07	1·86	1·60	2·00	2·08	2·48	2·45	·89	2·09	1·80	2·81	1·53
1·78	3·98	3·14	6·23	1·30	4·10	3·01	3·35	2·16	3·12	2·37	5·25	2·61	4·94
1·78	5·21	1·32	5·86	1·00	3·20	1·33	3·34	1·24	2·71	·77	2·27	1·39	2·79
3·75	1·89	6·06	2·38	3·10	2·50	2·21	2·71	3·91	2·19	4·05	1·72	5·00	3·91
6·86	5·33	10·38	8·50	3·50	3·10	4·25	2·10	8·52	4·05	5·28	3·57	8·13	5·13
1·97	3·19	3·16	6·45	1·55	2·60	1·77	2·46	1·31	5·05	1·32	3·03	2·62	4·67
4·03	5·60	5·83	9·42	3·60	4·00	2·90	3·82	2·07	4·70	1·10	3·82	3·63	4·36
40·00	48·53	59·15	71·40	26·65	38·10	27·63	37·18	38·32	45·00	25·42	34·76	39·80	45·52

SCOTLAND.

Division XV.—West Midland Counties (*continued*).

Argyll (*continued*).

Height of Rain-gauge above	Castle Toward.		Airds, Appin.		Callton Mór.		Inverary Castle.		Lismore.		Hynish.	
Ground ……	4 ft. 0 in.		0 ft. 3 in.		4 ft. 6 in.		0 ft. 1 in.		3 ft. 4 in.		…………	
Sea-level……	65 ft.		15 ft.		65 ft.		30 ft.		37 ft. ?		…………	
	1870.	1871.	1870.	1871.	1870.	1871.	1870	1871.	1870.	1871.	1870.	1871.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
January……	3·99	3·39	3·20	3·60	4·01	4·45	3·00	3·00	1 69	4·24	7·61	8·04
February …	5·53	6·51	11·50	5·40	6·30	6·45	3·50	2·00	2·47	4 38	4·01	6·53
March ……	1·33	4·04	1·40	5·40	1·32	4·23	·50	1 50	·64	5·10	2·85	7·87
April ………	2·48	5·43	4·40	2·70	2·39	3·69	3 00	·50	2·41	1·84	4·45	3·74
May ………	3·98	2·44	5·30	1·20	4·59	2·17	7·00	1·00	3·34	·93	6·27	1·65
June ………	2·32	2·65	2·80	1·90	3·09	2·70	2·50	2·00	2·36	1·64	2·78	2·23
July ………	2·68	3·94	5·10	5·00	6·71	5·81	2·00	5·00	3·13	3·64	4·16	4·58
August …..	2·03	4·00	2·20	4·00	1·40	3·29	2·00	6·00	1·39	1·48	·76	1·23
September…	3·80	1·61	5·90	1·80	4·70	1·97	5·00	1 00	4·36	1·38	8·07	3·74
October ……	6·21	4·69	6·60	5·00	9·19	4·85	9·00	1·50	6·48	2·35	8·17	5·90
November …	2·52	3·72	1·90	5·70	2·61	5·16	2·50	6·00	1·64	3·94	4 63	8 12
December ..	4·19	5·68	3·00	9·00	3 95	7·51	2·00	12·00	1 76	4·86	5·77	3·75
Totals …..	41·06	48·10	53·30	50 70	50·26	52 28	42 00	41·50	31·67	35·78	59·53	57·38

Division XVI.—East Midland Counties (*continued*).

Perth (*continued*).

Height of Rain-gauge above	Loch Katrine.		Auchterarder House.		Stronvar, Loch Earn Head.		Trinity Gask.		Scone Palace.		Strath-tay, Logierait.	
Ground ……	0 ft. 6 in.		2 ft. 3 in.		0 ft. 4 in.		0 ft. 1 in.		2 ft 6 in.		1 ft. 0 in.	
Sea-level……	830 ft.		162 ft.		460 ft.		133 ft.		86 ft.		313 ft.	
	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in	in.
January ..	5·00	6·10	2·15	2·75	5·03	8·05	2·78	2·26	2·05	2·31	2·40	1 67
February …	9·80	9·40	3·70	3·20	14·10	7 82	3·16	3·68	2·80	3·95	5·68	4·08
March ……	1·30	6·20	·70	2·30	2·43	7·90	30	2·30	·56	1·50	·49	2·03
April ………	3·60	4·80	·70	5·20	3·10	4·70	·28	5 30	·24	4·28	·79	2·55
May ………	7·30	1·80	2·20	·85	6·10	2·10	2·00	·60	1·45	·83	1·90	·69
June ………	1·80	2·60	·90	1·25	2·55	2·92	1·00	1·85	·96	2·22	·75	2·18
July ………	2·90	6·00	1·30	3·50	2·60	8·05	1·65	4·30	1·20	4·10	·86	4·06
August ……	1·20	6·40	1·30	2·80	·70	5·75	1·40	3·30	1·04	2·07	2·12	3·28
September…	6·60	2·40	2·10	1·40	7·32	2·28	3·00	2·10	2·12	1·85	3·54	1·19
October ……	11·30	8·70	4·30	3·75	10·25	7·95	3·76	4·10	3·30	3·56	4·08	3·25
November …	2·90	6·40	·70	2·00	3·25	5·75	·90	2·20	1·42	2·16	1·82	1 16
December ..	3·70	9·20	4·00	2·85	3·90	12·30	4·36	2·70	4 25	·84	2·70	3·12
Totals ……	57·40	70·00	24·05	31·85	61·33	75·57	24·59	34·69	21·39	29·67	27·13	29·26

SCOTLAND.

Div. XV.—(*continued*).				Division XVI.—East Midland Counties.											
Argyll (*continued*).				Clackmannan.		Kinross.		Fife.		Perth.					
Corran, Loch Eil.		Ardnamurchan.		Dollar.		Loch Leven Sluice.		Nookton.		Kippenross		Deanston.	
0 ft. 4 in. 14 ft.?		3 ft. 6 in. 82 ft.		0 ft 6 in. 174 ft.		0 ft. 10 in.		0 ft. 6 in. 80 ft.		0 ft 4 in. 100 ft.		0 ft. 4 in. 130 ft.	
1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.	1870	1871.	1870.	1871.	1870.	1871.
in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
4·65	6·65	2·37	3·64	3·60	2·94	2·20	2·30	2·21	1·31	4·30	2·50	3·94	2·93
4·30	9·40	1·49	2·71	3·80	6·23	1·00	4·40	2·00	3·89	2·60	4·10	4·23	5·70
2·75	7·95	·97	2·74	·27	3·73	·50	1·80	·77	1·06	·10	2·45	·51	3·48
6·10	1·85	1·82	1·17	1·36	6·43	·50	5·30	·50	5·17	·20	4·20	1·21	4·40
5·41	1·65	2·09	1·30	3·53	1·04	1·70	·80	1·72	·90	2·20	·45	2·96	1·10
5·65	1·05	1·91	·81	1·98	2·32	1·80	2·30	1·91	2·32	1·00	2·30	1·71	1·87
5·80	5·95	3·20	3·30	1·88	3·93	·80	4·40	·97	3·90	1·80	4·20	2·05	5·35
2·50	7·70	1·84	2·93	1·42	2·64	·70	2·40	·95	2·32	·50	3·10	·95	4·11
8·85	2·25	4·95	2·32	4·11	2·74	2·60	2·20	2·47	1·44	2·20	1·60	3·15	1·90
8·40	5·00	5·10	5·19	4·24	2·94	4·20	4·20	3·24	3·24	4·50	2·30	5·31	3·54
1·70	3·85	2·94	4·28	2·35	3·56	1·50	2·70	1·55	3·43	1·20	2·20	1·33	3·13
4·20	11·95	2·30	7·22	3·07	3·49	3·90	1·30	3·40	1·98	3·10	3·16	2·87	4·30
60·31	65·25	30·98	37·61	31·61	41·99	21·40	34·10	21·69	30·94	23·70	32·40	30·22	41·81

Division XVI.—East Midland Counties (*continued*).						Division XVII.—North-Eastern Counties.							
Forfar.						Kincardine		Aberdeen.					
Dundee. Necropolis.		Arbroath.		Montrose Asylum.		The Burn, Brechin.		Braemar.		Aberdeen.		Leochel, Cushnie.	
0 ft. 5 in. 167 ft.		2 ft. 0 in. 60 ft.		... ... 200 ft.		0 ft 4 in 235 ft.		1 ft. 0 in. 1114 ft.		0 ft 4 in. 95 ft.		3 ft. 0 in. 882 ft.	
1870.	1871.	1870	1871.	1870.	1871.	1870.	1871.	1870	1871.	1870.	1871.	1870.	1871.
in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in	in.
1·70	·90	1·60	1·10	1·50	1·00	2·20	1·80	·80	·61	1·38	1·30	1·36	1·01
2·10	4·20	2·36	3·00	2·40	4·35	4·00	4·70	4·40	3·62	2·52	3·42	4·03	3·03
·80	·75	·68	·69	47	·56	·70	·70	·37	2·73	·83	·38	1·43	·70
·30	6·10	·39	5·51	·65	5·11	·60	4·40	2·03	2·65	1·50	4·16	1·08	4·09
1·15	·85	1·20	·72	1·47	2·12	2·40	·70	2·66	1·06	1·36	·63	2·38	·91
1·55	1·80	1·83	1·42	2·98	1·62	·90	1·80	1·28	1·90	·83	1·06	1·30	2·50
1·25	3·00	1·11	3·21	4·34	4·34	1·70	5·20	1·97	3·74	3·03	2·85	2·72	4·42
1·40	1·75	1·70	1·48	·72	2·36	·30	2·50	4·79	2·49	·80	2·21	1·81	2·63
2·65	1·95	2·14	2·49	2·54	3·10	3·10	2·00	3·68	3·72	1·91	1·76	3·05	3·30
3·15	3·50	3·59	2·78	4·92	3·52	4·20	5·40	4·00	4·51	2·55	3·57	3·76	4·08
1·85	2·60	2·18	2·90	3·28	4·17	3·90	2·60	2·45	1·70	2·39	2·42	3·44	1·75
4·25	1·25	3·62	1·39	5·74	1·49	4·70	1·40	1·95	1·62	4·90	1·42	5·95	·95
22·15	28·65	22·40	26·69	31·01	33·74	28·70	33·20	30·38	30·35	24·00	25·18	32·31	29·37

IRELAND.

Division XX.—Munster.											Div. XXI.—Leinster.	
	Cork.				Kerry.		Waterford.		Clare.		Carlow.	
Height of Rain-gauge above	Cork, Queen's College.		Fermoy.		Kenmare, Killarney.		Waterford.		Killaloe.		Fenagh House, Bagnalstown.	
Ground	6 ft. 0 in.		4 ft. 0 in.		4 ft. 0 in.		4 ft. 0 in.		5 ft. 0 in.		1 ft. 5 in.	
Sea-level......	65 ft.		114 ft.		100 ft.		60 ft.		123 ft.		340 ft.	
	1870.	1871.	1870.	1871.	1870	1871.	1870.	1871.	1870.	1871.	1870.	1871.
	in.	in.	in.	in.	in.	in.	in.	in	in.	in.	in.	in.
January	4·76	4·92	3·50	4·32	3·37	7·50	4·75	4·81	5·75	4·96	4·12	3·48
February ...	4·39	4·47	3·07	4·55	4·67	6·78	3·26	3·93	3·02	3·70	2·83	3·31
March	2·24	2·64	2·55	2·28	4·96	3·78	2·99	2·18	2·74	2·52	2·34	2·04
April	1·14	4·48	·91	3·19	5·63	2·48	·82	4·51	2·07	4·92	1·01	3·57
May	2·38	·65	2·16	·66	4·95	·06	3·50	·71	3·93	·99	1·96	·24
June	·64	4·22	·78	3·10	·26	5·70	1·29	3·74	·71	2·75	1·06	2·25
July	1·01	4·67	·91	3·80	·28	7·53	·47	5·02	1·30	5·99	1·53	4·45
August	1·60	2·05	1·16	1·53	5·51	5·14	2·17	3·57	2·49	2·81	2·83	2·72
September ...	3·44	4·59	2·75	2·87	12·68	3·98	2·36	2·60	3·66	2·02	2·63	3·00
October	6·70	3·43	6·18	3·82	16·51	7·05	5·74	5·31	9·91	4·50	3·86	3·85
November ...	3·33	5·06	2·23	1·92	8·66	4·43	3·78	4·39	2·20	2·00	2·34	2·37
December ...	3·98	4·20	2·89	3·52	1·53	8·29	2·42	3·90	3·00	3·54	2·51	2·60
Totals	35·61	45·38	29·09	35·56	69·01	62·72	33·55	44·67	40·78	40·70	29·07	33·88

Division XXII.—Connaught (continued).							Division XXIII.—Ulster.					
	Roscommon.		Sligo.				Cavan.		Enniskillen.		Antrim.	
Height of Rain-gauge above	Holywell.		Doo Castle.		Mount Shannon, Sligo		Red Hills, Belturbet.		Florence Court.		Aghalee, Lurgan.	
Ground	5 ft. 6 in.		1 ft. 0 in.		4 ft. 5 in.		0 ft. 9 in.		11 ft. 0 in.		1 ft. 0 in.	
Sea-level......	....		....		70 ft.		208 ft.		300 ft.		105 ft.	
	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.	1870	1871.
	in.	in.	in.	in.	in.	in.	in	in.	in.	in.	in.	in.
January	3·28	2·98	3·31	4·57	3·32	4·11	4·19	4·33	4·86	4·49	2·95	3·33
February ...	2·74	3·62	4·12	3·86	2·26	3·34	2·51	3·36	5·38	4·75	1·91	2·84
March	1·58	2·15	2·23	3·06	3·30	3·21	1·54	2·83	1·44	3·93	1·46	1·35
April	1·46	3·22	1·72	4·18	1·75	3·51	1·16	3·31	2·01	4·56	1·20	2·86
May	1·68	1·34	3·30	1·42	2·86	1·06	2·91	·92	3·62	1·17	2·18	·55
June	1·81	4·27	1·53	3·65	2·22	2·71	1·22	2·09	1·13	1·91	1·06	2·02
July	2·12	5·49	1·66	5·64	1·86	6·53	1·65	7·82	·27	8·22	2·25	5·09
August	2·48	2·48	·86	2·41	3·05	2·66	1·24	2·46	1·38	3·37	1·45	3·00
September...	3·32	1·95	3·59	2·21	4·07	1·55	3·35	2·03	3·74	2·19	2·29	2·56
October	5·92	2·21	9·92	3·67	10·12	3·21	7·60	2·59	12·15	3·57	7·57	2·41
November ...	1·93	1·92	2·56	2·57	3·25	3·26	1·86	1·78	2·64	4·24	1·57	2·02
December ...	2·90	1·99	3·41	3·60	4·15	3·35	3·22	2·52	4·35	3·89	2·97	2·15
Totals	31·22	33·62	38·21	40·84	42·21	38·50	32·45	36·04	42·97	46·29	28·86	30·18

IRELAND.

Division XXI.—Leinster (*continued*).										Division XXII.—Connaught.			
Carlow (*continued*).		Queen's Co.		King's Co.		Wicklow.		Dublin.		Galway.			
Brownes Hill, Carlow.		Portarlington.		Tullamore.		Fassaroe, Bray.		Black Rock.		Cregg Park.		Galway, Queen's College.	
1 ft 0 in. 291 ft.		1 ft. 2 in. 240 ft.		3 ft. 0 in. 235 ft.		5 ft. 0 in. 250 ft.		29 ft. 0 in. 90 ft.		3 ft. 0 in. 130 ft.		8 ft. 2 in. 30 ft.	
1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.	1870.	1871.
in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
3·14	3·59	2·83	3·43	2·81	3·43	4·20	3·79	2·59	3·16	3·82	3·60	4·11	6·44
2·42	2·78	1·75	2·00	1·82	2·14	3·36	3·98	2·68	2·63	2·97	2·81	2·72	4·78
2·41	1·75	2·28	1·46	2·67	1·75	3·15	1·72	2·12	·68	1·22	3·02	1·45	2·21
1·08	4·61	·93	3·17	·98	4·00	·65	3·47	·65	2·86	1·81	4·98	2·61	3·44
2·75	·41	2·15	·63	2·12	·45	2·27	·32	1·20	·16	3·79	·86	4·36	1·28
1·06	2·37	·86	2·33	·69	2·71	·48	3·08	·70	2·54	·98	3·97	1·45	3·50
·74	5·20	1·17	5·62	1·07	6·29	·46	4·11	·68	5·94	1·33	4·95	3·43	6·20
1·99	2·62	1·61	1·97	1·49	1·70	2·20	1·24	1·96	1·10	1·99	2·14	3·29	3·64
2·65	2·19	2·95	1·60	2·66	1·19	2·64	4·46	1·32	4·10	3·02	1·39	3·51	2·18
5·60	3·13	6·54	2·83	5·54	2·29	8·64	3·48	6·64	2·84	6·09	3·48	9·69	2·20
2·21	1·82	1·04	1·65	·65	1·44	2·19	1·81	1·54	1·11	·89	1·46	4·57	1·38
2·19	2·63	1·93	1·82	2·36	1·70	2·90	1·79	2·94	·99	2·10	4·18	3·65	2·44
28·24	33·10	26·04	28·51	24·86	29·09	33·14	33·25	25·02	28·11	30·01	36·84	44·84	39·69

Division XXIII.—Ulster (*continued*).													
Antrim (*continued*).						Londonderry.		Tyrone.		Donegal.			
Antrim.		Belfast, Queen's College.		Carrickfergus		Londonderry.		Omagh.		Letterkenny		Dungloe.	
1 ft. 0 in. 150 ft.		7 ft. 4 in. 68 ft.		1 ft. 0 in. 18 ft.		0 ft. 6 in. 80 ft		1 ft 0 in 280 ft.		1 ft. 8 in. 108 ft.		0 ft 6 in. 10 ft	
1870.	1871.	1870.	1871.	1870.	1871	1870	1871.	1870.	1871.	1870.	1871.	1870	1871.
in.	in.	in.	in.	in.	in.	in.	in.	in	in.	in.	in.	in.	in.
2·22	3·18	2·44	4·38	3·37	3·41	3·00	4·44	2·87	4·11	3·93	5·70	2·73	4·37
1·74	2·64	2·65	3·24	2·81	3·67	2·55	2·50	2·61	2·42	4·11	3·50	3·30	2·70
·91	1·63	1·40	1·78	1·21	2·01	1·05	3·05	·80	2·04	1·77	4·48	1·68	4·37
·86	3·90	1·35	3·22	1·83	4·12	2·20	4·12	1·76	3·75	3·26	4·42	2·35	3·22
2·38	1·03	2·64	·58	2·58	·87	2·04	·16	2·84	·67	3·16	1·29	2·10	1·23
1·69	1·94	1·21	1·97	1·20	1·58	1·70	2·40	1·55	2·33	2·70	3·82	2·02	2·84
2·60	6·29	1·61	3·86	2·27	5·00	1·95	6·20	2·06	5·79	1·82	9·43	2·14	5·77
2·87	1·78	2·09	2·83	·57	3·97	2·40	2·80	2·15	2·19	2·33	3·50	2·78	2·29
2·36	3·14	1·43	3·39	2·23	2·54	4·53	3·78	3·15	1·67	5·90	2·78	4·70	3·63
7·60	2·57	9·90	3·08	8·31	2·44	9·80	1·63	7·70	2·49	11·05	4·74	8·50	4·12
·75	2·52	1·03	1·74	1·36	2·99	2·50	3·40	2·15	1·47	4·49	4·50	4·02	3·58
2·56	2·11	2·39	1·84	2·96	2·45	3·55	2·70	2·33	2·50	4·90	4·47	2·86	5·53
28·54	32·73	30·14	31·91	30·70	35·05	37·27	37·18	32·06	31·43	49·42	52·63	39·18	43·65

Report of the Committee, consisting of the Rev. Dr. GINSBURG, W. HEPWORTH DIXON, Rev. Dr. TRISTRAM, *F.R.S.*, General CHESNEY, Rev. Professor RAWLINSON, *and* JOHN A. TINNÉ, *appointed for the purpose of undertaking a Geographical Exploration of the Country of Moab.*

Report on the Exploration of Southern Moab.
By CHRISTIAN D. GINSBURG, *LL.D.*

THE expedition left London on Wednesday, January 10th, 1872, and arrived at Jaffa on Monday, January 22nd, about eleven o'clock in the morning. The party consisted of Dr. Ginsburg, Dr. Tristram, and Mr. Johnson. Mr. Klein, the original discoverer of the Moabite Stone, arranged to join them at Jerusalem. The object of the expedition was to get to Moab as soon as possible; it was determined not to tarry in the Holy Land, however much some of us felt tempted to explore the country. We therefore proceeded, at 3.30 P.M. on the same day, to Ramleh, taking Lydda on our way to Jerusalem. Early in the morning of the following day (January 23rd) we started for Jerusalem over Beth-Horon, and reached the sacred city in the dark.

After waiting six days at Jerusalem for an escort, and making the necessary preparations, we left for Hebron January 30th, at 10 A.M., where we arrived about six o'clock in the evening of the same day. Here we engaged Abou Dachouk, the Sheikh of the Jehalin tribe, to conduct us safely to Kerak. He entrusted his old uncle, Abou Salama, to head the escort; and we left Hebron at 1.30 P.M. on Thursday, February 1st. As it had been determined to enter Moab by the south, we now made our way to Engedi, and arrived at Um Ghazelat at 5.30 P.M.

Though this place is halfway between Hebron and Engedi almost in a straight line, and though the old Abou Salama, our guide (who, like his ancestors, was born and brought up in this neighbourhood), has acted as a guide to former explorers, yet he does not seem to have mentioned Um Ghazelat to those few travellers who have come this way before to explore the basin of the Dead Sea, nor can it be found in the most recent maps of Syria.

We pitched our tents for the night at this supposed new place, near the encampment of the Raabneh tribe. At 10.5 A.M. on Friday (February 2nd) we left for Engedi, where we arrived at 4.30 P.M. Here we encamped near the beach of the Dead Sea, and opposite the Moab shore and mountains, to which we were making our way. We left Engedi in the afternoon of the following day, which was Saturday, and determined to pitch our tents for Sunday at Sebbeh.

Between Engedi and Sebbeh we passed on the shore of the Dead Sea the following four Wadys:—Wady Ghar, which is close to Engedi, and which we crossed at 12.37 P.M.; this Wady, which our old Sheikh solemnly assured us was Ghar, is marked both in Van de Velde's and in Lynch's maps as Areyeh. The next is Wady Chobrah, which, according to Mr. Klein's most painstaking cross-questioning, we found to be the proper spelling, and not Khuberah, as it is spelled in Van de Velde's map; this Wady, which we reached at 2 P.M., is an hour and twenty-three minutes from the former one. The third Wady, which is an hour's distance from the second, and which is marked in Van de Velde as Wady Halîl, we were positively assured is Wady Mochrath; whilst the fourth Wady, which is about forty minutes' distance from the third, and which has no name at all in Van de Velde, we were told

is Nemriyeh. The distance between this Wady and Wady Seyal, where we camped, we did in a little less than an hour.

Having spent Sunday, February 4th, at Sebbeh, and explored the ruins of the famous fort, we started on Monday, at 7.45 A.M., for the Wady Zuweirah, where we arrived at 3.30 P.M., and encamped for the night. In the seven hours and three quarters which it took us to get from Wady Seyal to the Wady Zuweirah, we passed no less than ten Wadys, respectively called (1) Wady Sebbeh, (2) Wady el Kattar, (3) Wady Havhav, (4) Wady Senin, (5) Rabbat el Jumuz, (6) Wady el Kitter, (7) Wady Mersed, (8) Wady Chasrurah, (9) Wady um Berrek, and (10) Wady Nejd.

Of these ten Wadys, which are almost equidistant, only six are laid down in Van de Velde's map; and even of these six the names of three only correspond, the names of two out of the three being reversed (viz. Nos. 4 and 5 in this Report), whilst the names of the other three (viz. Um el Bedun, Wady Hatrura, and Um Baghek) are not to be found. It may be here remarked that Wady Nemriyeh, which, according to our guide, is on the south of Sebbeh, is in Van de Velde's map on the north, that the cliffs come up quite close to the sea between Wadys 8 and 9, leaving no beach whatever, and that we had here to make our way over the rocks. This fact is not pointed out in Van de Velde's map.

Being determined to cross the dangerous Valley of Salt early in the day, we left the Zuweirah at 6 A.M. on Tuesday, February 6th. Before leaving this remarkable spot we were determined to explore it, as well as the range of salt mountains which is known by the name of Khafhm or Jebel Usdum. It will be remembered that this is the spot marked in De Saulcy's map, as well as in the map of Palestine used in our British schools, as the site of Sodom; indeed De Saulcy declares that he saw here "the ruins of a building which was anciently a part of Sodom." Anxious as some of our party were to see the relics of the doomed city, a careful inspection of the heap of stones referred to left no doubt upon the mind that they are the remains of a mediæval square tower, which was erected here to protect the labourers in the salt mountains who carried on traffic with Hebron and other towns.

Between the Zuweirah and our entering the Valley of Salt we passed the marvellously torn and rent salt mountain, as well as three Wadys. Our Sheikh, Abou Salama (the brother of the very man who was De Saulcy's guide, and who gave him such minute information about the ruins of Sodom), could not even tell us the name of any of the Wadys. One of these had actually bored a tunnel through the salt mountain, and thus made a remarkable hole through the cave in Jebel Usdum. The beach now was nothing less than a soft slimy mud. The distance between the Wady Zuweirah and the extreme point of the Es Sabkah, where we began crossing it, is an hour and a half. At 7.30 we entered upon the margin of the barren flats of backwater. After marching for about three hours knee-deep in slush, and crossing seven drains, some of which were dry and some still draining, we arrived in the front of the Saphia at 10.3 A.M.

Here our troubles began. Seeing our cavalcade crossing the Salt valley, the Moabites must have thought that we were fair game for plunder, or that we were come to invade their homesteads. On approaching the Saphia, we found three tribes arrayed against us in front of the wood, beyond a narrow intervening stream. The grotesque mob, as we neared them, uttered shrieks, yells, and war cries, firing off their few guns, and refusing to let us enter their territory. Abou Salama, our old Sheikh, and Daud, our dragoman, with a few of our Bedouins, bravely jumped over the stream. The horses of

the old Sheikh and the young dragoman fell into the water, and the riders were soon seen rolling on the ground and struggling with their enemies. One of our Bedouins was lying prostrate on the ground, and bleeding profusely. After a few minutes the Sheikh and the dragoman were again on their legs and parleying with their assailants, assuring them with solemn oaths that we had not come to invade the country. We were at last allowed to cross, and were led by these bands of robbers into the Saphia, where a place of encampment was assigned to us about three miles towards the north.

After pitching our tents we clearly saw that our safety consisted in keeping together, and not straying singly into the wood, since these robbers were lurking behind the trees and bushes for prey. The three tribes who occupied the Saphia, and who now considered us fair game, are the Bene Attia, the Maaz, and the Warroney. We were, in fact, virtually prisoners, inasmuch as we did not venture to go beyond our tents; and we therefore deemed it more prudent to remain within our encampment the rest of the day, which was Tuesday, February 6th. In the mean time the robbers secretly despatched messengers to the Mugelly of Kerak to inform him that a batch of European magnates were in the Saphia, and that they too should come and have their share out of us. The son of the Mugelly Sheikh of Kerak, as it might be supposed, immediately came over and declared that we were in the hands of cut-throats and robbers, and that he came to save us from them. From the respect and deference which the Saphia tribes paid him we believed his declarations, and indeed began to feel ourselves more secure and at liberty.

We now determined to explore the Saphia and the extensive ruins in the neighbourhood. To do this we had to negotiate with the Saphia robbers, not only for permission but for escort. Their demands were exorbitant. As we decided to see what could be seen here we made the best bargain we could; and about 11 A.M., February 7th, we started on our explorations, accompanied by eight of the Saphia princes on horseback. Our direction was south-west of the Saphia, and we rode through a forest of acacia, thickets of tamarisk, and dwarf palms, till we came to very extensive ruins. These ruins, according to our guides, are divided into three parts; one is called Sheikh Isa (Jesus), the other Kasur el Bashaira, and the third the Mashnaka (hanging-place). In the second of these ruins we saw corpses of women lying about.

After carefully inspecting the ruins, which cover between one and two miles of the ground, it may be inferred that though the bulk of those which still rise to a considerable height above the ground are decidedly remains of mediæval sugar-mills and other buildings of that period, the foundations, and indeed the larger portion of the hewn stones strewn about, are as decidedly partly relics of buildings of the Roman period and partly the remains of edifices of a much older date than the Roman occupation of this district. They most probably exhibit the Moabite fortified frontier, both against the Jews on the west of the Dead Sea and against the Edomites on the east and south-east.

The fact that this is the southern frontier of Moab suggested another conclusion, which elucidates a geographical remark in the Pentateuch on the limits of Moab that is greatly obscured, and is perfectly without meaning in the authorized version. In Numbers xxi. 12, 13, we are told that the Israelites removed from Zared, "and pitched on the other side of Arnon, which is in the wilderness that cometh out of the coasts of the Amorites." This verse therefore gives the Arnon as the northern limit of Moab, thus

assuring the Israelites that all north of the Arnon up to Heshbon is to be theirs. In confirmation of this statement, the sacred writer quotes in the verse immediately following the declaration made respecting the frontiers of Moab from "The Book of the Wars of Jehovah," wherein the whole extent of Moab from south to north is most minutely fixed, and the two boundaries are distinctly specified, viz. the southern boundary is Vahab in Suphah [Saphia], and the brooks of Arnon the northern boundary.

Completely surrounded by the escort of these savages, we left our encampment at 8 A.M. As our tents were pitched almost in the centre of this oasis, we passed through, for about two miles, a forest of acacia, tamarisk, dwarf palms, and reeds on the shores of the Dead Sea, bearing north-north-east. At about 8.20 we reached the ruins of Um el Hashib, and about 8.40 we crossed the Wady Korcha.

The name of this Wady disclosed a remarkable fact, which Dr. Ginsburg believes will henceforth definitely settle a geographical point mentioned in the famous inscription on the Moabite Stone. On this triumphal pillar King Mesha tells us, in line 3, that he erected the monument in question at Korcha. In lines 21, 24, 25 we are told that this king built and greatly fortified Korcha after the expulsion of the Jews from Northern Moab; and though the word is treated as a proper name, and hence is without the article, yet epigraphists of great distinction maintain that the word, according to its form, cannot be a proper name, and therefore is the *Flat-land* or *Market*. Now the existence of a Wady named Korcha, spelled in exactly the same way as on the inscription, leaves it beyond the shadow of a doubt that Korcha on the Moabite Stone is the proper name of a town. When, in the sequel, we come to Dibon, we may be able to show the position of this town.

Going on still due north we came (*circa* 9.2 A.M.) in about twenty-two minutes from Wady Korcha to Wady Mirwacha, and in an hour and a quarter more reached the ruins of Numeira (*i. e.* circa 10.15). These ruins are in extent more than half a mile, and cover a surface of uneven ground. The stones of ancient buildings, which are strewn about in all directions, are mostly very large, about a foot and a half in diameter, but roughly cut. Some foundations of buildings, as well as the remains of a quadrangular wall, are distinctly discernible. The great geographical interest of this place arises from the fact that it figures on the maps of the few eminent travellers who have explored this region as the site of two remarkable places mentioned in the Bible. Thus Irby and Mangles (p. 448), as well as Lynch (p. 345), identify it with the ancient Zoar, to which Lot and his daughters fled for shelter at the destruction of Sodom; whilst De Sauley marks it as the site of Zeboim, which was destroyed at the same time as Sodom. The locality, however, as well as the name, correspond far more with the ancient Nimrim mentioned in Isaiah xv. 6, and Jeremiah xlviii. 34, than with either of these hypotheses.

Marching due north for about three quarters of an hour, we entered a thicket of thorny trees and bushes, and then crossed Wady Azzal at 11.30 A.M., leaving a fringe of reeds near the beach of the Dead Sea to our left. We continued our march north-east, ascending a hill and leaving the promontory or peninsula of Lissan somewhat to our left. We now ascended the southern portion of the ravine through which the Wady Drah flows into the Dead Sea, and crossed the Wady at about 2 P.M. Our journey was now almost due east, ascending all along by the side of the ravine; and at 3.30 we reached the top of the hill Drah, about 600 feet above the Dead Sea. The scene of our encampment here was most charming. To our left was the deep ravine

through which the Wady Kerak flows, with a perfect oasis on its slopes and with a Bedouin encampment. To our right there was a perpendicular mountain rising above us, on the summit of which are the ruins of an ancient tower, which was evidently designed to guard the pass to Kerak. At our back was the peninsula of El Lissan, and in front of us were the steep mountains of Moab, through the defiles and over the giddy heights of which we had to wind our way to Kerak. By the lurid light of our bivouac fires this remarkable spot looked sublimely lonely. The Mugelly with great cunning selected this place as best serving his purpose.

We retired to rest, little dreaming what we should have to wake to. In order to show how secure we were under his protection, and to lull us to sleep pleasantly, the Mugelly got up a sham fight with the Saphia robbers, charging them with mean behaviour towards us, and threatening to stab them, for which purpose he actually drew out his dagger. As it was an affair between themselves, quarrelling about the money we gave them to buy themselves a lamb for supper, we did not interfere, but went to sleep as soon as the deafening noise of these villains subsided, and rose early to resume our journey to Kerak, which was only four hours and a half distant.

It was here that the true character of the young Mugelly showed itself, and that we learned to our bitter cost why he urged us to dismiss our Jehalin escort, and why he adroitly selected this lonely spot for our encampment. No sooner did he perceive that we had begun to strike our tents than he demanded £70, and declared that he would not allow us to proceed unless the money was forthcoming. He at last consented to take 25 napoleons; and at about 8 A.M. we started on our journey. What might happen to us at Kerak when lodged in the clutches of this vagabond was more than any of us dared to think of. We tried to comfort ourselves with the fact that one of the gang was a Christian, and that he might be of help to us when the worst came to the worst. We proceeded on our journey not in a very good humour for exploring. We continued ascending a ridge of wild mountains, called Akabat Charaza, crossed the Wady Charaza, and came to the ruins called El Kabo (*i. e.* the cave), about 1000 feet above the Dead Sea (circa 9 A.M.). Here we were told a Christian Sheikh lived in olden days, who exacted tribute from all travellers to or from Kerak. The hill on the right of El Kabo is called Bothêneh, whilst the hill more to the north still is called Elmanzar (*i. e.* watch-tower). Ascending still higher we climbed a ferruginous hill, called Jebel el Hadid, passed Wady Umeshanan at 9.30, Wady Ruseis, with the spring called Ayin Ruseis, at 11.15, reached the plateau of Omsidré at 12, and descended to the bottom of Wady-Kerak at 12.40. We now began climbing an almost perpendicular zigzag, leading to the summit on which the ruins of this famous fortification, with its enclosed huts, are planted.

On our way to Kerak, the Mugelly was very anxious that we should camp outside this vulture's nest in the deep valley below, which is exceedingly fertile, and where there are ruins of ancient buildings and a sugar-mill. To this we decidedly objected, as we should have been cut off from all communication with the inhabitants, and in that case the vagabond could make any demand upon us without the possibility of our appealing to any one. He had therefore to lead us up to Kerak. The road consists of a very steep terrace on a charming ravine, strewn all over with stones of different shapes and various sizes. These stones being imbedded in the precipitous ascent, form, in fact, crooked steps. So steep is the ascent, that we had to dismount and lead our horses. We reached the top at 1.30 P.M.

It was fortunate that we went to examine the place immediately after our

arrival; for soon after we returned to our tents the son of the Mugelly, who brought us from the Saphia, came and demanded no less than 600 napoleons, as the remainder of the money for bringing us here and for allowing us to encamp at Kerak. We of course refused to pay any thing, and told him that, although he had extorted 25 napoleons from us, he had no right to act in this hostile manner. Seeing that we were determined not to be bullied out of any more money, he forbade us to leave our tents, and we thus became prisoners. In this plight we were visited by the Greek catechist, whom Mr. Klein knew. He procured us a messenger, whom we secretly despatched to Jerusalem with a letter to Mr. Moore, the British Consul, informing him that we were prisoners and that 600 napoleons were demanded of us.

As it was Saturday we made up our minds to a quiet rest in our tents for two days, which we did not grudge, as we were tired and wearied out with annoyance from the Kerak vagabonds. In the midst of our gloom, however, a ray of light appeared. We heard that Zadam, son of the Sheikh of the Bene Sachar, with whom Mr. Moore the consul had made a contract at Jerusalem to take us from Kerak to the north of the Arnon, had arrived here, and was the guest of the Mugelly.

The old Sheikh, the father of the Mugelly who had plundered us on our way from the Saphia, we had not seen as yet. We were told that he camped three hours from Kerak, that he was a better man than his rascally offspring, and that though "his belly, too, was as large as our tent, his mind was as wide as the ocean." We therefore sent a messenger to our future protector and guide Zadam, requesting him to come to our tents. At about 12 A.M. the old Sheikh of the Mugelly, with Zadam of the Bene Sachar, and a host of Moabite grandees came to pay us a visit. To this old Mugelly Sheikh in conclave we recited our troubles. He at once set us at liberty, and told us we were perfectly free to go where we liked, that his country was our country, and no man should dare to touch us or make any demand of us.

Our joy was now beyond bounds. We were not only set at liberty without money and without price, but we were told we might go wherever and do whatever we liked. To our further satisfaction we saw the old Sheikh taking his seat on the ground among his magnates, fifty yards from our tents, with his son opposite him in the ring, and heard him rating the scoundrel as hard and as loud as possible, telling him that he had brought shame and confusion of face upon his old father in the sight of these *Consuls* (which is the name they give to distinguished foreigners), and demanding that the 25 napoleons taken from us should at once be restored. We even heard that the money which had been divided between the chief robber and about a dozen minor scoundrels was actually being collected. Being thus set at liberty, we devoted the rest of Saturday and the following day to the exploration of this stupendous ruin and the town. The following is a summary of the results:—

The very entrance into this extraordinary ruin of Kerak, or the "Rock of the Desert" (*Petra Deserti*), as it was called in the middle ages, is remarkable. It consists of a long and winding passage of about 100 feet through a high ridge of the natural rock, which forms a cavern gate. It is in such a zigzag that we could not see those of our party who were fifteen yards before us. It is surmounted by an illegible Arabic inscription. Looking at it from the summit of the neighbouring mountains which overtop it, Kerak exhibits the form of a rude triangle; whilst from the bottom of the ravine it appears like a vulture's nest, constructed on a peak more than 4000 feet above the Dead Sea.

To understand the plan* of this fortification, it is necessary to bear in mind that the hill, the summit of which contains Kerak, rises on three sides from a deep valley, thus yielding natural buttresses, which, from their immense height and perpendicular form, defy any attempt at scaling them. It is only the north-west and south sides which are joined to the neighbouring mountains by crests of rocks; these, therefore, require artificial protection, and it is for this reason that the fortification consists of two distinct parts, viz. the tower on the north-west and the castle on the south.

The tower is a large oblong building of immense height, constructed of very huge and neatly cut sandstone. Viewing it from the town, it looks like three out of four skeleton walls of an unfinished edifice, being open towards the defile. It is furnished with galleries and staircases inside the thickness of its walls, putting the different stories of which it consists in communication with each other. It presents its three faces (the circumference of which measures about 131 yards) to the defence of the exterior, and is joined by its two extremities to the town which it was designed to defend. The stones of which it is built have been cut from the side of the rock on which it is erected. By this process the north-western side has not only been separated from its adjoining mountains, but the tower has obtained a very steep buttress. From the Arabic inscription *El Melek—Daher—Bybars* in the central wall, it is called "The Tower of Daher," or "The Tower of Bybars." It was within this three-walled tower that we camped, and were imprisoned in our tents. We saw Jerusalem most distinctly from the top of this tower. The castle or fortress on the south, which was designed to defend this side, left by nature unprotected, is in form a long square, widening towards the north, the north face being about 153 yards, the south 87, the east 218, and the west 240, thus making a circumference of about 698 yards. It is separated from the city on the north by a wide ditch, and is defended on the south by an immense reservoir, which is flanked by an enormous ditch, more than 98 feet wide, cut in the rock. A rampart, with galleries stretching across the length of the enclosure of the castle, divides it into two courts, viz. a lower court towards the east, and a higher court towards the west.

In the eastern or lower court is a chapel, with nave of 82 feet long, four windows, two in each side, and ending in a semicircular arch. There is a staircase in the thickness of the north wall, which leads to the platform on the top of the edifice. Irby and Mangles have noticed remains of large fresco-paintings, one apparently representing a king in armour, another the martyrdom of a saint who has his bowels twisted out, as well as an imperfect inscription in Gothic letters (p. 364). But with the exception of the inscription nothing is now to be seen. This court also contains the dungeon.

In the angle of the western extremity of the higher court is the gate of the castle, which leads, through a long and narrow passage, to two other doors furnished with portcullis and complicated defences. These had to be passed before entrance could be obtained into the enclosure. The court contains numerous cisterns and immense magazines of five or six stories high, which are now partly dilapidated. This castle was built about A.D. 1143 by Payen, who was cup-bearer to the King of Jerusalem, and who received Kerak as a fief after the execution of Knight Romanus.

* For a sketch of the plan of Kerak, as well as for an able treatise and some verbal communications on the same subject, according to which I have been enabled to correct and supplement my rough notes, I tender my best thanks to M. Mauss, the learned architect of the Duc de Luyne's expedition to the east of the Dead Sea. For the working out of the plan which was exhibited I am indebted to my wife.—C. D. GINSBURG.

Between the Tower of Bybars on the north end and the castle on the south, there are ruins of numerous buildings as well as an immense reservoir.

The plateau on which the town is built measures in its greatest length from north to south 852 yards, and in width from east to west 776 yards. Taking it as a rude triangle, the north-east face of the rampart measures about 1028 yards, the south face 868 yards, and the west face 732, making a total of 2628 yards. In other words, the plateau of the rock on which Kerak is built is not only more than 4000 feet above the Dead Sea, but is surrounded by a rampart more than a mile and a half in circumference, exclusive of the tower on the north and the castle on the south.

But though the fortifications are of the crusading period, some of the ruins in the town, and of the materials used in the construction of the modern dwellings, are decidedly relics of the Roman occupation of this place. These houses, which are some distance from the fortifications, are, as a rule, under the ground. They exhibit a very extraordinary appearance at a distance, since little more than the outlines of squares are visible above the ground. Dr. Ginsburg rode over several of them without perceiving that he was on the top of human residences. On going or descending into one of them, he found it consisted of one large room only, and had a few arches thrown across it, on which were the rafters. In this house, which was occupied by a relative of the Sheikh of Kerak, were the bases of four ancient columns, with a Mosaic pavement in the centre, of which the occupant made a circular hearth, with a raised rim around it. A fire was burning on it; and as there was no hole in the roof to serve as a vent, the whole room was full of smoke, so much so that he could not remain there more than a few minutes, much as he wished to examine the place. There were also raised recesses in the room, serving as a bed and as receptacles for corn. Part of the room also was set apart for the horse, and the goats too were admitted. There is not a single dwelling-place among the hundreds of houses with a window.

The population of Kerak is about 8000, about 6000 Mussulmans and 1600 Greek Christians. The former count about 2000 muskets, and the latter from about 500 to 600. After a minute inspection and examination of the ruins of the place, Dr. Ginsburg could discover no trace whatever to justify us in marking Kerak on our maps as the Kir Moab or the Kir Haraseth of the Bible.

We were now determined to make the best of our time; and having heard that the Sheikh of the Mugelly, who appeared as our second deliverer, was likely to disappoint us, we endeavoured to see as much as possible. We therefore started early on the following day accompanied by two horsemen, nephews of the Sheikh, to survey the neighbourhood of Kerak. We rode to the south of the town over magnificent ridges, down rugged and steep ravines, and across beautiful highland country from 8 A.M. to 5.30 P.M.

We first came to the place called Gelameh el Sapela, from which Ibrahim Pasha bombarded the town.

At 9.15, still travelling S.S.E., we reached the first ruin of Kirjathaim, which is on a hill. The stones which mark the basis of the walls are now in a different position from what they originally were, and distinctly show that the traces of the buildings which they indicate are of a much later date, probably of the crusading period. As the summit of the hill is only about 1000 yards in circumference, and as the ruins on the slope around do not extend very far down, the town must originally have been small. Still the immense stones which are strewn about in all directions, and the extensive caves on the ridges, show that it was in olden days a very strong and im-

portant place. There are terraces running down at regular intervals to the bottom of the hill.

At 9.20 we reached the sister hill, on which the second part of Kirjathaim stood. Its ruins are almost exactly like those on the other hill. And as the terraces here like those there descend all around, the rings of which they consist, as a matter of course, becoming wider and wider as they near the bottom, the last terraces of the two hills meet at the foot, and so connect the two parts of the town. For this reason the place was called Kirjathaim = "*the double-towned.*" In each part we saw a deep well, with thoroughly cemented walls, capable of holding a very large quantity of water. As the crow flies, Kirjathaim does not seem more than ten minutes from Kerak.

At 9.30 we left Kirjathaim, and in less than ten minutes we reached a place called Kirbath Nulet, and in about a quarter of an hour after (9.45) we came to Kirbath Aziza. Here we found an old wine-press cut in the rock, and on the other side of the ruin we saw an enormous well. A very little further on we came to Kirbath Nukad, and at 10.10 to Chorba Chaviya. We then reached (at 10.40) a tremendous natural cavern, called Gava, and got to Mochra at 10.53. This is a very extensive ruin, and has some remarkable cisterns, caverns, and other remains of former glory rarely seen in other places. The most interesting part of this place, however, is in its bearing on the history or geography of Moab as recently disclosed on the Moabite Stone, inasmuch as it supplies one of the two missing places mentioned on this Triumphal Pillar. In lines 13 and 14 of the inscription, Mesha, king of Moab, tells us that after capturing Ataroth and slaying its inhabitants, "the men of Gad who dwelled in it from time of yore," he repeopled the place with "the men of Mochrath." The context plainly shows that these men must have been faithful subjects upon whom the king could rely, and that hence their dwelling-place was south of the Arnon; but as far as our knowledge goes, no such place has hitherto been identified. There can therefore be hardly any doubt that this is the place.

Within five minutes of the above ruin (10.57) we came to a place in ruins called Gel-gul. After an hour and a quarter (12.7) we reached Mode, where we saw a Roman mile-stone. The inscription was so defaced that we could not decipher in which reign it was set up. At 1.25 we passed the Wady Medin. On our way back we examined the ruin Chorbath Theniah, which is close to Kerak. It is an extensive ruin, and it is rather remarkable that so large a fortification and town should have been erected so near the formidable forts of Kerak.

It was well that we had made use of our liberty thus to examine the neighbouring country; for on our return we found the old Sheikh with his retinue of sons, cousins, nephews, brothers, and officials sitting in council around and within our tent. He heard that we were to leave Kerak soon; and as he wanted a pretext to plunder us, he told us he had been informed that we had sent a messenger to Jerusalem to report his son's conduct. The fact is that the Greek priest, who for some reason or other expected money from us, and of course was disappointed, got to know that his catechist had secretly procured us a messenger, and reported to the Mugelly Sheikh that we had sent a letter to Jerusalem. What harm this could have done to the old Sheikh was a mystery, since he pretended to repudiate his son's robbery. The motive, however, was apparent. In spite of all his cunning devices to conceal it, we saw perfectly well that he wanted to extort money from us, and that he must do it at once. This pretended deliverer of ours therefore suddenly changed

into an insulted enemy. He declared in the midst of his people in our face, that he cared neither for the Governor of Nabulus nor for the Pashas of all the East, nor for the Consuls at Jerusalem, and that he was determined to send us back to the Saphia to the robbers, from whom he now said his son had delivered us. The young Mugelly had therefore no more made his face black by his conduct to us at the Drah as the old rascal declared before, but rendered us unspeakable service by saving our property and our lives.

This was now the story of the old Mugelly Sheikh, and to this we had to address ourselves. Our feelings may easily be imagined when we found our professed friend suddenly changed into as great a robber as his son. The Beno Sachar chief who came to Kerak to fetch us told us that it all meant money, and that we must make up our minds to submit to another extortion. The question was therefore discussed what would satisfy the old vagabond. We decided to give him twenty napoleons and his brother five napoleons, and with this he was satisfied.

With feelings of great relief we left the old ruined castle, congratulating ourselves that we had at last actually escaped from this fiery furnace. But we had not gone more than 300 yards when a very violent rain commenced, accompanied by a terrific hailstorm. The horses refused to proceed, and we had to return to take shelter behind the walls of the Greek church. In a few minutes we were wet to the skin, and it seemed that even the elements conspired against us to keep us at Kerak.

After waiting for an hour and a half behind the walls and among the tombs in this drenching flood, we made a fresh start at 12.30. The anxiety of the muleteers to get away was so great that they would not allow the storm to stop them, and had gone on without us. Our joy in leaving, which was now brightened by a little sunshine, made us forget that we had tremendous ravines to descend and precipitous heights to climb of thousands of feet. It was only when we were actually facing these giddy heights and depths that we began to think how their natural difficulties were now enhanced by the heavy rain. However, we got through without any further accident than some of the mules falling down and upsetting the luggage, which created a Babel of swearing and such an incessant shouting and clamouring amongst the Arabs as only those can realize who have ever had the misfortune to hear it.

On our way to Rabba, after ascending the next height, we passed along a beautiful highland, which might be made exceedingly fertile by a little cultivation; but these Bedouins prefer plunder to work, and only sow that which they absolutely require for themselves and cattle. The whole journey from Kerak to Rabba took us three hours and a half. We passed through Chorbath Rakin, a small ruin about an hour from Kerak, Bether, and Minchar. Whatever these places may have been in olden days, at present only large scattered stones and the bases of walls remain to show that at all events some of the buildings were strong and capable of defence. At four o'clock in the afternoon we reached Rabba.

This is supposed to be Ar, the ancient capital of Moab (Deut. ii. 9, 29). We camped on the site of an ancient pool, about 50 by 60 yards, and about 21 feet deep. There were three large caverns in the walls, which were a godsend to us; for it was pouring rain on our arrival here, and these caves afforded shelter to us and our horses whilst the tents were being pitched.

Between our camp and the ruins of Rabba there was about a quarter of a mile, and there were two more pools from which the ancient city derived its chief water-supply. As the rain continued we could not do more than inspect

the ruins before nightfall; but early in the morning Dr. Ginsburg and Mr. Klein went to examine them more closely. Unlike Kerak, Kirjathaim, and other ancient places, the ruins of Rabba, which are about a mile and a half or two miles in circumference, are situated almost on a level, with the exception of one part, which is on a very low hill. On the northern side are the remains of an old temple, with several columns still standing. There are on all sides caverns, large and small, cisterns of various dimensions, and wells of all sorts, which show that the place in its entirety must have been of great importance. There are, moreover, scattered among the ruins, large blocks of basalt, which are hewn into smooth stones for use, and which are evidently of much older date than the bulk of the ruins.

It was here they saw a basalt slab, of almost exactly the same dimensions as the celebrated Moabite Stone, which had evidently been prepared for an inscription, but which, for some reason, had been left uninscribed. Several others of smaller size were also seen, which, from their slabby appearance, were apparently intended for tablets. These ancient relics afford every opportunity to the dealers in Moab and Jerusalem, whose cupidity has been roused by the discovery of the Moabite Stone, to supply the demands of the market.

The impression that was formed of the ruins of Rabba is, that though there are among them many vestiges of the Roman period, such as pillars, cisterns, extensive roads, &c., there are very few relics of an older date. To examine Rabba thoroughly, as it ought to be done, one should remain on the spot, and work quietly for at least a week, turn up all the important stones, and investigate and measure all the various pools, cisterns, and caverns. This, however, we could not do. But after a close examination of the place and its surroundings, they came to the conclusion that Rabba is not the ancient *Ar*, the antiquated form of IR, or *AR Moab*, as it is stated on the most recent maps. Rabba is almost in the centre of Southern Moab, whilst the Scripture Ar Moab was on the confines of the Arnon, and marked the extreme northern limit of the trans-Arnonic Moab, Vahab in the Saphia defining the southern frontier (comp. Deut. ii. 36; Joshua xiii. 16; Numb. xxii. 36, and *ibid*. xxi. 13 and 14). The Greek name Areopolis was first given to the ancient Ar Moab on the Arnon, and afterwards, when Ar Moab was destroyed by an earthquake (comp. St. Jerome on Isaiah xv.), it was transferred to the modern Rabba.

We left Rabba at 8.25 (Feb. 15th) on Thursday. At 9.30, travelling N.N.E., we came to a place called Kasr Rabba (*i. e.* the Palace of Rabba). The ruins here, though small, are exceedingly massive. The stones of which the palace was built are enormously large; they are bevelled, and somewhat resemble those of the old wailing-place at Jerusalem. The bases and cornices of columns which lie about on the ground measure 4 feet 8 inches in diameter. The fact that in many parts of the shattered walls the bevelled part of the stones was turned the wrong way, shows that the buildings have been shaken by a violent earthquake.

In leaving Kasr Rabba at 9.55 we saw, at a distance to the left, ruins on a hill, which are called Shichan. On the greater part of the way to these ruins, the old Roman road is still most distinctly traceable. Whilst some of our party were marching with the mules to the Arnon, we galloped to Shichan, which we reached at 11.20. It is 4700 feet above the Dead Sea, and has a very remarkable cistern on its summit. The distance between Kasr Rabba and Shichan is about 8 miles. In descending the summit we found ourselves for at least a mile and a half on regular terraces, which had evidently been most carefully cultivated in olden days.

On leaving this place at 11.35, and marching to the Arnon, the change of the soil was extraordinarily sudden. From the fertile ground around these ruins we all at once came upon a most dreary wilderness, which was only relieved by tremendous holes in the ground, and by dried-up and stunted bushes. It was not till we came close to the verge of the Arnon that signs of fertility began to show themselves. We reached this awful ravine at 1.55 P.M.

The southern side, though not as perpendicular and as grand as the descent at Engedi, is exceedingly steep, being 2150 feet deep. It took us fully an hour and a half before we reached the stream at the bottom at 3.30. All the way down the traces of the old Roman road and unfinished Roman milestones are to be noticed. The stream is narrow and rapid, and to the right of the descent are still to be seen the ruins of two arches of the bridge, which, however, in its present form, is not older than the time of the Crusades.

The cliff at the northern ascent is 1900 feet high. As the road extends over a wider ground, it is on the whole not so steep. It took, however, quite as long a time to ascend it as the descent on the southern side occupied.

Here, where the maps put the ancient Aroer, Dr. Ginsburg and Mr. Klein left Dr. Tristram and his friends. A messenger had arrived from Jerusalem with the sad tidings of the dangerous illness of Mr. Klein's eldest child. He at once decided to return to Jerusalem, which was perfectly natural. Mr. Klein was the only one who could talk with the Arabs, and we were almost entirely dependent upon him for the information from the Bedouins. The Arabs pronounce the same word differently; and apart from a thorough knowledge of the language in all its various provincialisms, it requires great tact to obtain the necessary information from them. Mr. Klein, with his complete mastery of the language, and especially his intimate acquaintance with the ways, manners, and customs of the Arabs, not only knows how to get information out of them (a tact which he acquired by twenty years' residence among and intercourse with them), but, above all, he understands how to test the correctness of the information by a series of direct and indirect cross-questioning, which is quite an Eastern art. As it appeared to Dr. Ginsburg that Mr. Klein was thus an essential member of the expedition, he determined to return with him.

Dr. Ginsburg continues:—

We left the Arnon at 7.30 A.M., February 16th; travelling due north, almost all the way on the remains of the old Roman road, and passing the imaginary site of the Biblical Aroer, we came to the ruins which go by the name Dibân at 8 A.M., *i.e.* in about half an hour. From the fact that the famous Moabite Stone was discovered here, I devoted some time to the examination of the place. The whole of this once celebrated stronghold is in ruins; there is not a single hut to be found on the spot. The circumference of the ground on which the ruins lie prostrate is at least a mile and a half. Like Kirjathaim in the south of the Arnon, this town was originally built on two hills, the sloping terraces of which joined at the bottom; and by this means the place, which looked at a distance like two distinct cities at the top, was joined into one at the bottom. Notwithstanding its undoubted age, few traces of antiquity are to be seen among the shattered ruins of the walls.

The old stones have evidently been used up for later buildings; and it would require a sojourn in the place for at least a fortnight carefully to turn up the foundations and the heaps of ruins to ascertain whether some other valuable relics are to be discovered here.

From a careful inspection of the place in connexion with the ruins not far

off, I am convinced that it is not the site of the ancient Dibon, but of Korcha. My reasons for this conclusion are as follows:—i. In all the eight passages of the Bible wherein the name Dibon occurs (Numb. xxi. 30; xxxii. 3, 34; Josh. xiii. 9, 17; Isa. xv. 2; Jer. xlviii. 18, 22), no data are given to fix its exact site. The christening, therefore, of these ruins by the name Dibân, on the part of the Arabs, like the naming of many other localities, has been suggested by Biblical explorers. ii. The Moabite triumphal pillar which was found here gives us the direct information that Mesha erected it at Korcha, a city which this monarch built. As no one who will examine the enormously heavy fragments of this huge block of basalt, with its delicate inscription, will suppose that it has been brought here intact from another place without the inscribed letters being injured, the spot where it was found must be the site of its original erection. And, iii., between this place and the stream Vâleh, an hour's distance, there are several old ruins, the names of which our Bedouin guide could not tell. One of these is most probably Dibon.

After a careful investigation of this ancient site, we left to cross the north-Arnonic portion of Moab. Our route was now to have been over the upland. Going in a north-westerly direction, we passed several ruins, and crossed the stream Vâleh, about an hour from what is called Dibon. From this place, instead of pursuing the usual course, due north over the highland, our Bedouin took us westward, right over the range of mountains to Mayin, or what is supposed to be Callirrhoe. In this charming valley, to the hot springs of which Herod the Great resorted during his last illness, we pitched our tents close to the encampment of the Awazim tribe, to whose protection we were recommended by Abou Zadam of the Bene Sachar.

Early in the morning, February 17th, we left for the Jordan, escorted by Abou Wardy, the Sheikh of the Awazim. He, too, led us across the range of mountains instead of by the usual upland road. The most remarkable and significant part of my experience, bearing on the value of the information obtained from the Bedouins, I gained on this part of my journey. In looking at a map of Palestine, it will be seen that this range of mountains has played a most important part in the history of the Jews. From these heights Balak king of Moab, and Balaam the prophet of Baal, beheld the Israelites encamped on the Plains of Moab. From here Moses the great lawgiver saw the promised land: here he died and was buried. Here we passed across the very spot marked on the maps as Pisgah and Nebo.

We had with us, from the Arnon to Mayin or Callirrhoë, a Bedouin who was a native of Northern Moab, the whole extent of which is only about twenty miles in length and as many in width. The fact that he was the only companion of Zadam, the magnate of the Bene Sachar, and that with this chief he was to be our guide for more than a month, sufficiently shows that he was no ordinary man of his tribe. From Mayin again to the Plains of Moab and the Jordan we had with us the Sheikh of the Awazim himself, who was not only born and brought up in the neighbourhood, but is the chief of the whole district. Yet neither the second in command of the Bene Sachar nor even the chief himself of the Awazim could tell us a single name of gorge, valley, mountain, or ruin between Diban and the Jordan.

The reason of it is simply this. In Palestine, which has been visited by pilgrims ever since the fourth century, who came in search of the places wherein the events connected with the life of our Saviour have transpired, the law of demand and supply has brought to the surface whole regions which would otherwise never have been named. Those who came thousands

of miles under the greatest privations to do homage in the birth-place of the Saviour, on the various spots where the greatest of his miracles were performed, where he suffered, died, and was buried, were determined to have the scenes. Hence the different sections of the Church, inspired by pious devotion, and aided by the cupidity of the natives, have not only been able to discover the place of every event, but to secure for themselves severally a different spot where the same event was enacted.

The case, however, is different in Moab. Here no events connected with the life of Christ have taken place. Here no pilgrims have come in search of sites. Very few even of explorers have traversed the country. Hence the natives, who can neither read nor write, and who are dependent for information upon hearsay, have never heard from outsiders what places are wanted, and therefore do not know them, and cannot supply them.

Geographical Exploration of Moab. By Rev. H. B. Tristram, *F.R.S.*

The expedition for the exploration of the country of Moab, so liberally aided by the grant of the British Association, set out from Jerusalem on the 30th of January. Our party was reinforced by Mr. R. C. Johnson, who proved himself invaluable both as a surveyor and a photographer; Mr. Buxton, not less efficient as a photographer and observer; Mr. Hayne, who devoted himself with great success to the botany of the country; Mr. Mowbray Trotter, to whose gun we were indebted for many a meal; and the Rev. F. A. Klein, of Jerusalem, the discoverer of the Moabite Stone, whose thorough knowledge of Arabic and of the people and the country rendered him an invaluable member of the party, till suddenly recalled home by a melancholy domestic affliction.

We determined to enter the country from the south, as being the most difficult and least known route, our course being by Hebron, Engedi, Masada, or Sebbeh, Jebel Usdum, and thence across the Sebkha, or barren sand-flat, which extends for several miles to the south of the Dead Sea. This we accomplished with a guard of the Jehalin tribe of Arabs. At the edge of the Sebkha we were on the frontier-line of ancient Moab and Edom; and here we met with some little difficulty from a robber tribe, the Beni Atiyeh, with whom, however, after a faint show of hostilities and a few random shots, we were able to make terms. We found the Ghor es Safieh, which we were able to examine at leisure, very much more extensive southward and eastward than it is marked in the maps. It is, in fact, a fertile belt scarcely raised above the level of the Dead Sea, 16 miles from north to south, and fed by the numerous perennial streams and springs which gush from the lofty sandstone range that forms the buttress of the Hauts Plateau of Moab. On the heights above the southern extremity are the villages of Tufileh and Feifeh, on the banks of streams, which we were not able to visit. Our exploration of the Safieh was carried out under considerable difficulty, as the natives were lawless, and we could only move with an escort of horsemen. However, we were able to ascertain, in our rides with our guards and in several rambles on foot, that there are no remains of importance in the oasis itself. The principal ruins are of some extent, indicating a well-built village, with several fragments of columns and Roman work, called Kasr el Bushireh; and a little higher up is a tolerably perfect water-mill, and a Saracenic gateway of rather rude construction, belonging apparently to a ruined Khan; it is

now called "Mushnekkr," or "the gallows." No other ruins could we find. We explored on foot the widest part of the Safieh towards the Dead Sea, on the edge of which a rank vegetation of sedge and reed takes the place of the dense thickets of nubk and dom tree which stud the cultivated plain, here about four miles wide.

Leaving the Safieh we proceeded by the route of Irby and Mangles to Dráa. The day's journey led us through every conceivable variety of vegetation and non-vegetation. Leaving the Nahr el Hassan, the great source of fertility to the Safieh, we passed through a scrubby plain, rushes, canebrakes, and finally a bare salt marsh, without a scrap of vegetation to the sea, and a gravelly shelving slope, with scattered gnarled acacias above it; near its commencement is a ruined village, Um el Hashib, not far from the Wady Grahhih. The barren plain is fringed by a fetid ditch, well named Mir'whar, or "stinking river," with salt and offensively smelling liquid. Having crossed the salt plain, we came to the Nahr Hanyir and Nahr Nimeirah, salt streams. At this latter are the mean and almost obliterated ruins of a large place, apparently unfortified, and usually marked in the maps as the ancient Nimrim of Scripture. This, however, we have reason to believe is incorrect, as the position is defenceless; and we were told of ruins higher up near the sources of the stream in the mountains, which still bear the name of "the waters of Nimeirah." Near them is another Scripture locality, "the brook of the willows," which is given to the head of the next stream before it leaves the mountains.

A little above this lower Nimrim we visited the ruins of a fort, Khirbet es Sheikh, which appears to have been nothing more than a watch-tower to guard the road.

After crossing the Nahr es Asal, or Honey River, we began to ascend the shoulder of the Lisan, a mass of barren salt marl, without a trace of life, past or present, and in a few hours reached Dráa, generally said to be the ancient Zoar, after crossing the Wady Weydah, in which the palm-tree is abundant.

Dráa, though the seat of a bishopric in the time of Eusebius, has left no traces beyond lines of foundations and heaps of sandstone, some of them squared and dressed. But the deep glen on the crest of which the city stood is richly wooded with palm, oleander, and other trees; and its fertile belt can be traced by the eye as far as the Mezraah, a wide, scrubby, tree-dotted plain, opening on the bay to the north of the Lisan, and now covered with the tents of the Beni Atiyeh. This has been traversed by Messrs. Palmer and Drake.

From Dráa we ascended to Kerak by the route so well described by Irby and Mangles. A fort, hitherto unnoticed, guards the pass about halfway up, called El Kubboh. The character of the architecture is crusading, and the local tradition makes it the stronghold of a Christian Sheikh. Just to the south of this, the "Wady of the Willows" was pointed out to us. We calculated the ascent from Dráa to Kerak to be 3720 feet,—Dráa, though on the brow of a bold shoulder, being 570 feet below the sea-level, and Kerak 3180 feet above it (barometric).

Without pretending to compare the country with Switzerland, and at the risk of incurring the sneers of those who, judging only by bigness, accuse any one who is enthusiastic on Palestine of "Holy Land on the brain," any one less prejudiced than these critics will admit the pass to be a magnificent one, and the situation of Kerak to be majestic.

It has already been described by Irby and Mangles, and is sufficiently

known to students. The entrance to Kerak is certainly unique, by an arched natural tunnel in the side of a precipitous cliff, out of which the traveller emerges in the midst of the city. The photograph shows this gateway into Kerak. It is needless to describe the extraordinary position of the city and its natural and artificial strength against the resources of mediæval or modern Oriental assault. It was undoubtedly the strongest natural fortress in Syria before the introduction of modern artillery—a platform of a triangular shape, each side from ½ to ¾ mile in extent, inaccessible except by exposed mountain-paths on all sides, save where a neck of land connects it with the adjoining mountains, and this cut through by a wide fosse of 30 feet deep and touching massive walls 18 feet thick above it.

The fortifications, Phœnician or Jewish in their lower parts, then Roman, surmounted by the work of Crusaders, are of vast extent and enormous height. The photographs give some idea of the vast labour expended on these works.

We found Kerak as little hospitable as have our predecessors in this land. The Mudjilli, though holding a Turkish commission, is practically independent, and is an unscrupulous, avaricious, and cunning chieftain. We were held as prisoners for some days to ransom, after entering under his son's safe conduct; but our imprisonment was not severe, though rather costly.

On one day, when our keeper relented, we were able to go out with a guard, and ride many miles to survey, while the rest of the party photographed nearer home.

Our survey proved very successful in fixing the sites of many ruined places, some of them hitherto unknown by name, and the others erroneously placed in all the existing maps. Our course lay chiefly south for twelve miles, and thence back by a detour to the eastward. Crossing the deep valley of Tziatin, where the soldiers of Ibrahim Pasha were slaughtered in 1844 in attempting to cut their way from the north, we marked the position of Jelam es Sebbha, where Ibrahim Pasha had his camp; and then of Kureitin (evidently an ancient Kiriathaim), the remains of twin ancient towns close together, each on a low knoll. This fashion of two adjacent towns with the same name seems to have been very prevalent throughout the whole of Moab.

Here we found ourselves on the high tableland which forms the country of Moab, studded thickly in every direction with ruined villages and towns, always situated on gentle swellings—Kirbet Azizeh, Kirbet Nekad, M'hheileh, Howeiyeh, Jubah (on the old Roman road), Mahkhennah (mentioned by Irby), Modeh, Abou Taleb, Mesh'had, and several others. Modeh, like Kureitin, has been a twin city, and there is a Roman milestone, unmutilated, close to it, of the date of Antonine. At none of these ruins did we find any water, but wells and cisterns innumerable, from fifty to one hundred in each place, generally one for each house, and oil-presses and wine-presses cut in the rocky slopes. We returned by Madin, more extensive ruins than the others. Here were sarcophagi and sculptured fragments, and house-walls quite perfect, but without a trace of mortar between the dressed stones. We saw, but did not visit, the ruins of Moureyah, Hamad, Suhl, and Nachal, mentioned by Irby.

From the Kerak people we obtained a long list of names of ruined sites known to them, upwards of sixty in number, some of which seem the Arabic representatives of Hebrew names. Dimnah (perhaps the Dimon of Isaiah, commonly held to be identical with Dibon), Lubeirah, Sumrah, Yaroud, Betir, Hadadah, Rahun, Zérar, Hhómoud, Azour, and others.

In a few days, by the aid of Sheikh Zadam of the Beni Sakkr, we were

able to leave Kerak without the payment of a very heavy ransom (£70 in all), and started for the north.

It must be remembered that Kerak is the one inhabited place in the whole country, the only town or village in the vast and once densely peopled region between Es Salt in Gilead and Shobek, a little village in the ancient Edom.

Passing the ruins of Suweiniyeh and Duweineh, after descending from Kerak, and ascending again more than 1000 feet, we rode through the ruins of Rakim and Mikhersit, from which place we followed the Roman road to the ancient Rabbath Moab, now Rabba. These are some of the most extensive and finest ruins in Moab; but the incessant rain prevented our taking any successful photographs. We camped inside an immense Roman tank, 60 yards by 50, and, though filled to a considerable extent with the refuse of the goats which are herded there, still nearly 30 feet deep.

The city seems to have been a square, more than a mile each way. One fine temple has some columns and two arches left; but all else are only broken walls, with long lines of straight narrow streets and countless vaults arched over. The ruins are Roman, but with many carved stones from earlier edifices built in, and many dressed blocks of basalt, telling of a still more ancient city. There are several green mounds covering extensive masses of masonry, which might probably repay excavation.

From Rabba we followed the Roman road northward, passing a very perfect little Roman temple, one and a half mile from the city, and soon afterwards a ruined town (the remains of which seem anterior to the Roman occupation), Missdehh, and immediately afterwards Humeitah, the Hammat or "Animah" of Palmer, probably an ancient Ham.

Kasr Rabbah, or Beit el Kurm (the house of the vineyards), four miles north of Rabbah, has possessed a magnificent Corinthian temple; the diameter of the columns, many of which with the frieze are standing, is 4 feet 8 inches. Hence the Roman road divides, one line going towards Shihan, the other, more easterly, to the passage of the Arnon. The former crosses the gentle depression which marks the commencement of the Wady Ghurweh. An easy slope reaches to the top of Jebel Shihan, on the southern side of which, lining the Roman road, are very singular remains, countless small enclosures, fields or gardens, all formed of blocks of basalt, undressed, and no limestone employed; they cover many acres. The road here has been only 15 feet wide. The city itself, on the top of the hill, has been built chiefly of limestone, with very little basalt. The cisterns are numerous and of considerable depth; but they, as well as the wells, are now all dry.

Descending by N.E. we passed through the ruins of Balh'ua, and overtook the rest of our party, who had followed the other route. Near the edge of the ravine of the Arnon are the remains of an old fortress, Kirbet Sum'hra, and then Muhatet el Haj, conjectured to be the Jahaz of Scripture, shapeless ruins.

The passage of the Arnon has been described by several of our predecessors, who have certainly not exaggerated its magnificence or their fatigues. By our barometers the depth is 2150 feet, and the southern plateau is 200 feet higher than that to the north. The Roman paved way may be frequently traced, as well as the remains of the bridge below. From crest to crest, we computed by triangulation to be about three miles. The upper part of the southern side reveals a superficial basaltic stream, which is absent on the north. There are numerous ruined forts all along the Roman causeway. On the northern brow, a mile east of the road, are the ruins of Arar, the ancient

Aroer; and "the city that is in the midst of the river" (Josh. xiii. 16) is no doubt indicated by the remains in the luxuriant strip of semitropical verdure that fringes the Arnon far below it.

Here, from the news of a sad domestic affliction, brought to us at Rabbah by a messenger who had been beaten and robbed of the letters by the scouts of the Kerak ruffians, Mr. Klein, to whose aid we are really indebted for the success of our expedition, through his masterly knowledge of the language and his friendship with the Beni Sakkr, was compelled to leave us and return hastily to Jerusalem. He was accompanied by Dr. Ginsburg.

From the northern crest of the Arnon bank a good view could be obtained of the general lie of the Wadys which here furrow the high land.

The Arnon, or Wady Mojib, is formed a little above where we crossed it by the junction of three ravines of nearly equal height, the northern one named by Zadam Wady Seideh, the name given in all the maps to the central one, and the others Mákhanas and Balhua.

A ride of three miles across a dreary highland plain brought us to Dhiban, another double city on two knolls, whose caverns, cisterns, underground storehouses, and semicircular arches present no peculiar features. To the west of both knolls is a little stream, near which the famed monolith was found, and in which water was running. All the surrounding hills are limestone, and there is no basalt except what has been brought here by man. It is needless to say that no inscribed remains now exist above ground; but we found a very finely dressed basaltic oil-press, with the upper stone lying close to the outer cylinder, by the bank of the stream.

From Dibon we struck eastward, by the route taken by Messrs. Palmer and Drake, towards Um Rasas. The road lay up a wide depression, which could scarcely be called a valley, known as Kurm Dhiban (the vineyards of Dibon), and continuously for three miles were the traces of the vineyard-ridges across the slopes. These are "the plains of the vineyards" of Judges xi. 33, the route taken by the Amorites after their discomfiture by Jephthah. Rujum Selim, a shapeless inconspicuous heap, is the only ruin on the way from Dibon to Um Rasas. This latter seems placed too far east by Palmer, who has also erroneously marked the Hadj road as touching it, and placed it ten miles too far west—a mistake not to be wondered at when we consider the very great difficulties under which Mr. Palmer and Mr. Drake accomplished their visit.

A Roman road does, however, touch Um Rasas from Heshbon to the south. Um Rasas was of necessity very hastily examined by our only predecessors, and is of much greater extent than had been imagined. The outline of the city and its walls, apparently repaired at a later period, is perfect,—no grass-grown mounds, but simply fallen or falling buildings, with streets encumbered by the masonry and countless arches; no heathen temples within the city, but five Christian churches, one of them probably a cathedral, and all of the Basilica type. The apse was generally perfect, with the plinth and beading decorated by bosses carved with alternate heads and crosses. Some of them we photographed. Outside where we were camped was the amphitheatre, now grass-grown, and several very deep cisterns, not very large superficially.

The most interesting ruin here is a Christian mortuary tower, which Mr. Palmer has sketched, close to the ruins of a Byzantine church, of which we took photographs. This tower is a landmark for miles round, and ludicrous traditions are locally attached to it.

Um Rasas appears to me to be probably the "Thamatha" of the 'Notitia,'

the station of the first Valentian "Ala;" and the name is preserved in the Wady Thamed close by. It certainly must have been one of the most important cities in these highlands in the Roman times, and is on the Roman military road.

We made expeditions eastwards to the ruined fort M'seitbeh, where there was abundant water in a large cistern, and the Hadj road eleven miles east of it, east of which is the ruined Khan Zebib, which places have never before been visited. Khan Zebib is evidently built on the ruins and with the débris of a former great city; and to the east of it are the remains of an interesting Doric temple. Jemail (two and a half miles south of Um Rasas) and Ghazal (Khazaleh of Palmer's map) were also visited. At both of them there was water, and traces of vineyards in the neighbourhood. Khan Zebib is above the rise of the Wady Shabek, the head feeder of the Zerka Main or Callirrhoe, a wide shallow basin fed by the drainage from a limestone range to the east of it.

The Hadj road is here closely marked by about fifty parallel furrows, formed by the tread of long lines of camels pursuing the same tract for ages in succession.

Near the great temple east of Khan Zebib are numerous natural caverns, which form subterranean labyrinths, and have been cemented and used as reservoirs in past ages: now they seem occasionally employed as hiding-places and folds by the Bedouins. Beyond these are a number of artificial mounds and circles of stones, affording unquestionable evidence of the cairns of the primæval inhabitants.

We spent several days at Um Rasas, in the hope of securing a stone which is buried there, but which the Bedouins would not reveal to us. I have seen a squeeze of this stone, which is now in the possession of Dr. Dodge, of Beirut, having been taken by a Bedouin before the stone was buried; it is of basalt, and bilingual. The centre is occupied by a serpent biting a scorpion. On the serpent are inscribed numerous Phœnician characters, and on one side is a long inscription of many lines in the Phœnician character; on the other, arranged in a similar semicircular fashion, one in apparently Nabathean letters. I hope ere long to obtain a copy of this important inscription.

From Um Rasas we travelled N.W., passing Beihar and the ruins called Drá, a Moabite city of the very oldest type, probably the Zoas of Eusebius, and the seat of a bishopric. This place has not been previously noticed, and solves some of the difficulties which have encumbered the topography of the Zoas of the Pentateuch.

In two hours we crossed the Wady Thamed, overhanging which, on a peninsula formed by the river, is an immense heap of stones, apparently an old keep and enclosure. It is 300 feet above the Wady, and is known as Um R'mail. We made this our station for a few days. Three miles north of it is Zafaran, with a fort of large squared stones on the top of a till, and the remains of the town below it. There are no traces of arches here, and the place seems pre-Roman. It may perhaps be the Naar Safari of the 'Notitia,' the station of the second Ala miliarensis. Near it are the similar ruins of El Alaki, and two miles further El Herri, a fortress on a knoll and a town below it, with the old Roman road passing close by.

The next ruin, N.E. from hence, is Um Weleed, one of the most important and extensive in the whole country. The ruins are of three distinct types, pre-Roman, Roman, and a Saracenic Khan. No previous traveller has visited it, and its local name gives no clue to its ancient name. The Roman road passed

through it. There is an amphitheatre; the pavement of a forum, surrounded by the bases of columns, is entire, 41 paces by 38, and just beyond it the eastern gate of the city, outside which is an interesting little Doric temple, 12 yards by 10, facing east, the niches being still *in situ*.

The streets here have been arcaded; and we found in some places the flat slabs of stone which formed the flooring of the dwellings above the streets still entire. By the side of these old streets the ancient Khan looked but a work of yesterday.

We followed the Roman road from Um Weleed to Um el Kuseir. There is no ruined bridge as marked in the maps; but there is a long massive wall across part of the plain, built for the purpose of guiding the floods into the cisterns. Um el Kuseir is of the same type as the last named city, but not so extensive.

Hence we struck eastward to Ziza, where we spent a week. It is mentioned in the 'Notitia' as the headquarters of the Dalmatian Illyrican cavalry. The remains of Ziza are very perfect. The tank is simply magnificent, 140 yards by 110 (see Photograph): many of the stones are 6 feet in length. Much engineering ingenuity is shown in the mode by which the upper valley has been banked, and a system of sluice-gates arranged for filling the pool and letting off the superfluous rainfall.

Above it is a strong Saracenic fort, still entire, and which was occupied by Ibrahim Pasha. The upper story has been fitted for engines of war, and many stones taken from Christian chambers marked with plain symbols appear in the walls. The ancient city is on a long ridge further up, occupying several acres, and full of sculptured ruins. The whole hill is honeycombed with cisterns. The principal remains seem not earlier than the Christian period, comprising several churches.

Six miles east of Ziza we crossed the Hadj road, not far from the base of the limestone range which forms the eastern limit of the highlands of Moab.

A little beyond this, at the very base of the hills, but without any trace of water, we discovered a palace which surpasses in interest any other of the ruins which this expedition has brought to light. From the eminences near Ziza we had detected a pile of masonry in this direction; the Beni Sakkr gave it the name of Mashita, and spoke of it as being like the other ruinous heaps which we were continually examining.

A gazelle had beguiled our ride, and not a little were we startled when we reined in our horses in front of a façade of which only the photographs can give the slightest idea. Two days were well spent in photographing and measuring (see Plan and Photographs). We were in utter perplexity as to the origin of these magnificent buildings; nor was our difficulty lessened by the long lines of inscriptions in an unrecognized character on the lower corners outside the inner palace. One thing was plain, the palace had never been finished, at least in its decorations; and we have to thank Mr. Fergusson for having given us the clue to the solution of the problem. Mr. Fergusson is decidedly of opinion that it is the work of Chosroes II., the Sassanian king of Persia, after his conquest of Syria, North Arabia, and Egypt in A.D. 611–622. The builders seem to have been interrupted, for it is evident that the decorations were never finished. This is explained by the advance of the Emperor Heraclius, who so brilliantly swept the Persian out of the whole of his conquests, and recalled for a moment the glories of old Rome.

There are no more ancient remains of any kind in the neighbourhood, and no Saracenic additions whatever. Mashita stands forth in absolute solitude and isolation, unlike the cities of Moab, with their traces of many

epochs. It probably was erected as a hunting-palace, to gratify the luxurious taste of Chosroes. Mr. Fergusson has pointed out the indications in this wonderful sculptured façade of Byzantine art, guided by Persian design (see Plan and Photograph).

It is not a little strange that so perfect and unique a building has remained unnoticed and undiscovered by any European before us, and without any tradition attaching to it by the Bedouin. There is no trace here of any destruction by the hand of man. The sculpture is of extraordinary depth and scarcely weathered, as may be seen by the photographs.

Travelling north from Ziza, the ruins of Kustul, evidently some Roman "castellum," possess, as may be seen from the photographs, a character distinct from any other Moabite cities. There are the several walls, cisterns, and arches, these latter unusually massive and well finished; but besides them two castles, with many semicircular bastions, surmounted by a sculptured balustrade of the Corinthian order. The principal castle is 84 yards square.

The smaller castle, isolated from the city, would seem to have been a temple fortified. We found a Greek altar of white marble, and several marble capitals, which must have been imported from the Greek islands or Asia Minor. Below the city is a tank like that of Ziza.

Six miles north of Kustul I visited Thenib, a heap of cisterns, walls, and arches, and two miles further north Rujum Hamam, a ruined heap of shapeless stones. This was our extreme north-eastern point.

Travelling west from Kustul, Um Zibarah presents only a large assembly of hummocks and hollowed cisterns. Crossing the commencement of Wady Jifar we reached the top of Jebel Jelul, a most remarkable hill, hitherto unnoticed, or placed close to Heshbon, rising 300 feet above the plain and covered with ruins. Pieces of Doric entablature were strewn about. The panorama from Jelul was uninterrupted for several miles in all directions.

From Jelul, turning south, we passed Sufa, crossed Wady Habis, the ruins of Betan el Bareil, Habis city, and then leaving the highlands followed down the gorge of the Habis, the main feeder of the Zerka Main. Owing to the ruggedness of the road it was a two days' journey to the hot springs of Callirrhoe. We had now left the country of the Beni Sakkr, and were in that of the Hamaydeh. These latter have been spoken of as an independent tribe, and the remains of the ancient Moabites. We never found them inhabiting huts, but only tents like other Bedouins; physically they seemed decidedly inferior to the Beni Sakkr, who treat them as mere vassals, pasturing their cattle and camels where they please in Hamaydeh territory, and summoning them to their service. They obeyed the orders of Zadam implicitly, when he desired Ibn Tarif or any other of their Sheikhs to act as our guides in any part of their country. Nor were we once asked for backshish from the time we left the Kerak men till we reached Jericho. Their chief men never presumed to enter the tent with Zadam, but consorted with the servants. The gorge of the Callirrhoe is one of the grandest I have seen. We had to ascend to a narrow secondary plateau and then descend 1300 feet to the hot baths. The north face of the ravine is red sandstone below and white limestone above; the south face is formed by a stream of basalt, in many places columnar.

Our camping-ground was delicious, by the side of a warm sulphur torrent, 96° Fahr. just where it dashes into the cooler stream of sweet water in front of us. The hot sulphurous springs all issue from the north face of the gorge, at the junction of the red sandstone with the limestone. In a reach of three miles there are ten principal springs and many minor ones, dashing down

little nullahs or canons, all shaded with date-palms and canebrake. The temperature of the upper spring was only 85°, that of the fifth and tenth, which are the largest, was 135° and 140° at their exit from the rock. The heated stream of the Callirrhoe retains a temperature of 70° at its mouth.

There is not a trace of Roman baths or of building of any kind; this is not to be wondered at when we observe the rapid deposit of sulphur now forming about all the lower springs. These sulphurous deposits form crumbling cliffs, under which the hot stream has in many places made itself a tunnel, to which the Arabs have pierced holes through the overlying crust, over which they sit and enjoy a natural vapour-bath.

We made this lovely glen our headquarters for eight days, and thoroughly examined the neighbourhood. The castle of Machærus (M'Kaur), the place of the martyrdom of St. John Baptist, does not seem to have been noted by any predecessor, and is wrongly placed in the maps. It stands to the S.E. of the head of the Wady Sgara, the next glen to the south of Callirrhoe. Its natural position is accurately described by Josephus; but there is nothing left to give any idea of the great strength of its fortifications. The citadel, isolated, as Pliny observes, from the city below, has only foundations of the keep just level with the soil, circular, exactly 100 yards in diameter; within it is a well of great depth, a large and deep oblong cemented cistern, and two *dungeons*, one of them very perfect. The town occupied the ridge of a long crest running east and west to the west of the fortress, and is marked by a stupendous heap of stones, beyond which are the foundations of several forts and of a small temple. The stone heap is 250 yards long and of great height, and the crest is 3800 feet above the Dead Sea. The finest view on the east side is, I think, from the top of the ridge between M'Kaur and Callirrhoe.

Attarus, the ancient Ataroth, and Kureiyat (Kiriathaim) were also visited. Attarus is certainly in extent among the most considerable of the Moabite ruins, but featureless; Jebel Attarus is three miles distant from the site which bears the name of ancient Ataroth. It has been crowned by a massive square fortress. The feature most remarkable in this treeless country is a fine terebinth, which attracts the eye from far and is noticed by Burkhardt. Round this hill and in the undulating plain between it and the city the ground is sparsely covered with trees, the only wooded spot in the highlands. Terebinths, oaks, and especially the almond-tree in abundance, present an aspect most refreshing in this bare and monotonous land.

Kureiyat has nothing worthy of note, and from hence to the Arnon there is scarcely a ruin on the eastern edge of the plateau.

In the neighbourhood of the Callirrhoe we observed several prehistoric stone circles, like those found at Beitin and elsewhere, and many cairns, which seem far anterior to the mounds of the cities.

An expedition to Zara (the Zareth Shaphan of the Bible) was full of interest. The narrow ravine of the Callirrhoe it was impossible to follow; and we were compelled to mount the heights, cross two more gorges, and follow the crests till we descended 2000 feet from a lower plateau upon the oasis of Zara. This is not, as marked on the maps, at the mouth of the Callirrhoe, but considerably to the south. It was a city of Reuben, its frontier town on the shore, and shows few traces of later occupation. We may trace the features of the Jewish town, a central fort on a knoll and the houses clustering round it, as may be seen to-day at Gibeon and elsewhere. We were surprised to find a wide extent of rich land fringing the Dead Sea, abundantly watered by hot springs, some sulphurous and others sweet. This belt reaches to within a short distance of the mouth of the Arnon. Northwards some bold

headlands intervene between it and the Callirrhoe, and a scramble we had to get round to the fissure through which the river emerges, forming a spit covered with tamarisk at its entrance. It is needless to say that we found the shore-line laid down by Lynch most accurate, but the sketching-in of the country, even close to the water's edge, most inaccurate, as his party in this district seem rarely to have left their boats. There is a striking contrast between the eastern and western shores; on the latter there are only a few patches of verdure, scarcely breaking the desolate barrenness of the coast-line; on the east all is exuberant verdure and continually running streamlets to the water's edge. The palm-tree is abundant, and clings to the sides of the little ravine from a height of over 1000 feet to the very edge of the sea (see Photograph), while the varying shrubs and flowers overpower the botanist. This must be attributed to the sandstone formation, which, underlying the eocene deposits, nowhere appears on the west, while it is greatly elevated on the eastern side.

Arrived at the mouth of the Callirrhoe, we ascended the gorge on foot with an ibex-hunter for our guide, and though the scrambling was severe, were richly rewarded. At the shore the cliffs are 600 feet high, and the opening only 100 yards across, sometimes, as we ascend, only 30 yards. It winds and turns suddenly, and the glow of the red sandstone walls is gorgeous. Paths or tracts of course there are none; and we were compelled to climb as best we could up the side, when a waterfall, Jebel Moia, *i. e.* "waterhill," barred all progress.

After having thoroughly investigated this district we turned northwards, visiting at leisure the sites on the western edge of the highlands where the cities of Moab were most crowded.

In this region, as far as Heshbon, I must notice the great number of dolmens which everywhere occur in these parts, which are too rocky to have been ever subjected to the plough; I have counted more than twenty in one morning's ride. They are all of one pattern, three stones placed endwise forming three sides of a square, and a large stone forming the cover, generally about six feet in diameter. I never found four supporting stones.

We followed a road, Jewish or Roman, to Maon and then to Medeba. On every side are the foundations that mark the boundary-walls of fields or vineyards, while the Belka Arabs here, for the first time, exemplify the natural fertility of the country by their cultivation of large tracts in wheat and barley.

For the ruins of Main (Boal Meon), which occupy four adjacent hills, and of Medeba, which retains its Bible name unchanged, I can but refer to our photographs.

At the latter we camped for some days and visited the ruins to the east and north. Medeba contains more perfect Roman remains than any of the other western cities of the highlands. It is not in a hollow, but, like all other towns of Moab, on the top of a knoll. The forum, or whatever else it may have been, is the largest we have seen, 280 by 240 yards, with a colonnade, and the bases of the columns still *in situ*, many temples and later christian churches. The most remarkable remaining work is the reservoir, built on the same principles as Solomon's pools, and 120 yards square, with its walls 30 feet thick at the base, tapering to 18 feet. It would be tedious to describe the temples and churches of Medeba, which at least prove the dense population of this part. The other northern cities of Moab call for no special mention; they occur every half mile, and are alike in their main features. Man has had little or nothing to do with their decay. We examined carefully the

heights overhanging the Dead Sea with a view to Nebo. The modern Nebbeh affords exactly the view described in Deuteronomy, and I can find no other to rival it. The city of Nebbeh is lower down on a spur of the range, and with remains more perfect than ordinary. The whole country is here densely crowded with ruins; but the names do not indicate their ancient equivalents —Maslubiyeh, Kuseir, Et Tein, &c.

From Nebbeh we worked to Ayun, Mossa, Heshban, &c., which have been visited by many others. We made some sojourn in the Seisaban, and identified Ramah, Beth Jesimoth, and other scriptural sites, and thence worked down the shore of the Dead Sea towards Callirrhoe. We ascertained that the Seisaban, the ancient plains of Shittim, is of very much greater extent than the maps represent. The fertile Ghor extends from the Beit Nemeirah, or upper fords, to within 3 miles of the mouth of the Callirrhoe, and is well watered throughout; but in ancient warfare this region could never be defended, and the ruins are unimportant, though there is not a single mound without the stones which tell of some fort of the olden time.

We trust we have by our expedition carried out the intentions of the British Association. We have carefully mapped the whole country north of the Arnon, every previous map of which we found to be a mere work of the imagination. We have left no ruin in that tract unexplored; and though we have brought home no Moabite stones, we never dreamt we should be able to do so. The grant was for *geographical exploration*, and that we have endeavoured conscientiously to carry out, and have brought to light some twenty ancient cities hitherto unvisited and unknown, and others known only by name. The zeal of my companions enabled me to exhibit about 100 photographs.

Sur l'élimination des Fonctions Arbitraires.

By CH. HERMITE, *Corr. Member of the Mathematical Society, London.*

[A communication ordered by the General Committee to be printed *in extenso*.]

C'EST la définition géométrique d'une famille de surfaces par un certain mode de génération qui a conduit à définir analytiquement une fonction z de x et y par le système de deux équations

$$\left.\begin{aligned}\phi(x, y, z, \alpha, A, B, \ldots L)=0,\\ \psi(x, y, z, \alpha, A, B, \ldots L)=0,\end{aligned}\right\} \quad \ldots \ldots \quad (1)$$

où entrent un paramètre variable α et un nombre quelconque n de fonctions arbitraires de α, représentées par A, B, ... L. Obtenir une équation aux différences partielles, à laquelle satisfait la fonction z quels que soient α et ces n fonctions, sera la question traitée dans cette note par une méthode nouvelle.

J'observe en premier lieu que les relations données permettent de considérer x et y comme des fonctions de z, dont les dérivées successives,

$$x'=\frac{dx}{dz}, \quad x''=\frac{d^2x}{dz^2}, \quad x'''=\frac{d^3x}{dz^3}, \ldots$$

$$y'=\frac{dy}{dz}, \quad y''=\frac{d^2y}{dz^2}, \quad y'''=\frac{d^3y}{dz^3}, \ldots$$

s'obtiendront, soit directement si l'on peut avoir x et y explicitement exprimés en z, soit par les règles relatives aux fonctions implicites. Dans ce dernier cas nous aurons d'abord,

$$\frac{d\phi}{dx}x'+\frac{d\phi}{dy}y'+\frac{d\phi}{dz}=0,\quad \frac{d\psi}{dx}x'+\frac{d\psi}{dy}y'+\frac{d\psi}{dz}=0,\quad . \quad . \quad . \quad (2)$$

puis :

$$\left.\begin{aligned}\frac{d\phi}{dx}x''+\frac{d\phi}{dy}y''+\left(\frac{d^2\phi}{dx^2},\frac{d^2\phi}{dxdy},\frac{d^2\phi}{dy^2}\middle\rangle\!\middle\langle x',y'\right)_2+\frac{d^2\phi}{dxdz}x'+\frac{d^2\phi}{dydz}y'+\frac{d^2\phi}{dz^2}=0,\\ \frac{d\psi}{dx}x''+\frac{d\psi}{dy}y''+\left(\frac{d^2\psi}{dx^2},\frac{d^2\psi}{dxdy},\frac{d^2\psi}{dy^2}\middle\rangle\!\middle\langle x',y'\right)_2+\frac{d^2\psi}{dxdz}x'+\frac{d^2\psi}{dydz}y'+\frac{d^2\psi}{dz^2}=0,\end{aligned}\right\}\ (3)$$

et ainsi de suite.

En second lieu je remarque que $z=f(x, y)$ étant la fonction qui résulte de l'élimination du paramètre a, on reproduira identiquement la quantité z si l'on y remplace x et y par les valeurs qu'on tire de la résolution des équations (1), car autrement ce serait de deux relations conclure une troisième qui en serait distincte. D'après cela et en regardant x et y comme fonctions de z, la première dérivée de l'identité obtenue donnera l'égalité suivante :

$$\frac{dz}{dx}x'+\frac{dz}{dy}y'-1=0 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

la seconde et la troisième celles-ci :

$$\frac{dz}{dx}x''+\frac{dz}{dy}y''+\left(\frac{d^2z}{dx^2},\frac{d^2z}{dxdy},\frac{d^2z}{dy^2}\middle\rangle\!\middle\langle x',y'\right)_2=0,\quad . \quad . \quad . \quad . \quad (5)$$

$$\left.\begin{aligned}\frac{dz}{dx}x'''+\frac{dz}{dy}y'''+3\left[\frac{d^2z}{dx^2}x'x''+\frac{d^2z}{dxdy}(x'y''+x''y')+\frac{d^2z}{dy^2}y'y''\right]\\ +\left(\frac{d^3z}{dx^3},\frac{d^3z}{dx^2dy},\frac{d^3z}{dxdy^2},\frac{d^3z}{dy^3}\middle\rangle\!\middle\langle x',y'\right)_3=0\end{aligned}\right\}\ (6)$$

les quantités x', x'', x''', y', y'', y''' devant être remplacées par leurs valeurs en fonction de z, ou éliminées au moyen des relations (2), (3), &c. En continuant les mêmes calculs jusqu'à la dérivée d'ordre n, on parviendra à un système de n équations, où les dérivées partielles de l'ordre le plus élevé seront évidemment :

$$\frac{d^nz}{dx^n},\ \frac{d^nz}{dx^{n-1}dy},\ \ldots\ \frac{d^nz}{dy^n},$$

et, en y joignant les deux relations proposées, il sera possible d'effectuer l'élimination du paramètre a et des n fonctions arbitraires A, B, . . . L. C'est le résultat cherché qui est ainsi *une équation aux différences partielles d'ordre* n.

Dans le cas le plus simple de $n=1$, lorsqu'il n'existe qu'une seule fonction arbitraire, cette équation aux différences partielles s'obtient immédiatement en résolvant par rapport à a et A les équations

$$\phi(x, y, z, a, \text{A})=0,\quad \psi(x, y, z, a, \text{A})=0\ ;$$

ayant en effet

$$a=\Phi(x, y, z),\quad \text{A}=\Psi(x, y, z),$$

il ne restera plus trace du paramètre ni de la fonction arbitraire dans les relations (2) qui deviennent :

$$\frac{d\Phi}{dx}x'+\frac{d\Phi}{dy}y'+\frac{d\Phi}{dz}=0,\quad \frac{d\Psi}{dx}x'+\frac{d\Psi}{dy}y'+\frac{d\Psi}{dz}=0\,;$$

et le résultat de l'élimination de x' et y' entre ces équations et l'équation (4) est immédiatement donné en égalant à zéro le déterminant :

$$\Delta=\left\{\begin{matrix}\frac{dz}{dx}, & \frac{d\Phi}{dx}, & \frac{d\Psi}{dx},\\ \frac{dz}{dy}, & \frac{d\Phi}{dy}, & \frac{d\Psi}{dy},\\ -1 & \frac{d\Phi}{dz}, & \frac{d\Psi}{dz}.\end{matrix}\right\}$$

Sans m'arrêter à tirer de là les équations aux différences partielles des cylindres, des cônes etc., je prends pour exemple les *surfaces réglées* dont la génératrice est la droite :

$$x=Az+B,\quad y=az+C,$$

ce qui nous donnera un cas d'élimination de trois fonctions arbitraires. Or ayant

$$x'=A,\ x''=0,\ x'''=0\,;\quad y'=a,\ y''=0,\ y'''=0,$$

les équations (5) et (6) deviennent simplement

$$\left(\frac{d^2z}{dx^2},\ \frac{d^2z}{dxdy},\ \frac{d^2z}{dy^2}\between A,a\right)_2=0,$$

$$\left(\frac{d^3z}{dx^3},\ \frac{d^3z}{dx^2dy},\ \frac{d^3z}{dxdy^2},\ \frac{d^3z}{dy^3}\between A,a\right)_3=0,$$

et il ne reste plus qu'à effectuer l'élimination de $\frac{A}{a}$, ce qui est bien en effet le résultat connu.

La considération des surfaces enveloppes, où s'offre un mode de génération entièrement différent des précédents, conduit à définir une fonction z de x et y par deux équations contenant un paramètre variable a, et dont l'une est la dérivée de l'autre par rapport à ce paramètre. En désignant de nouveau par A, B, . . . L, n fonctions arbitraires de a, ces conditions s'expriment ainsi :

$$f(x,y,z,a,A,B,\ldots L)=0,\quad \ldots\ldots\ldots \quad (7)$$

$$\frac{d}{da}f(x,y,z,a,A,B,\ldots L)=0,\quad \ldots\ldots\ldots \quad (8)$$

et nous nous proposons encore de former entre la fonction et les variables indépendantes, une équation aux différences partielles qui subsiste quelles que soient ces fonctions de a.

A cet effet je conçois que x et y soient déterminés par les équations (7) et (8) en fonction de z, de manière à avoir toujours les relations précédemment obtenues :

$$\frac{dz}{dx}x'+\frac{dz}{dy}y'-1=0,\quad \frac{dz}{dx}x''+\frac{dz}{dy}y''+\left(\frac{d^2z}{dx^2},\ \frac{d^2z}{dxdy},\ \frac{d^2z}{dy^2}\between x',y'\right)_2=0,\ \text{etc.}$$

Mais je procéderai différemment pour calculer les dérivées :

$$x' = \frac{dx}{dz},\quad y' = \frac{dy}{dz},\ \text{etc.},$$

en mettant à profit une circonstance importante qui s'offre lorsqu'on veut tirer de ces équations les dérivées partielles $\frac{dz}{dx}$, $\frac{dz}{dy}$. Différentiant pour cela la première par rapport à x, en supposant a fonction de x, y, z, il vient

$$\frac{df}{dx} + \frac{df}{dz}\frac{dz}{dx} + \frac{df}{da}\frac{da}{dx} = 0,$$

ou simplement d'après l'équation (8),

$$\frac{df}{dx} + \frac{df}{dz}\frac{dz}{dx} = 0;$$

et on obtiendrait de même :

$$\frac{df}{dy} + \frac{df}{dz}\frac{dz}{dy} = 0.$$

Or nous n'avons plus dans ces relations les dérivées des fonctions arbitraires par rapport au paramètre, et nous en tirerons les quantités cherchés x', y', ... exprimées au moyen seulement de A, B, ... L, en observant que $\frac{dz}{dx}$, par exemple, étant une fonction entièrement déterminée de x et y, que j'appellerai pour un moment $\theta(x, y)$, on aura

$$\frac{d\theta}{dz} = \frac{d\theta}{dx}x' + \frac{d\theta}{dy}y';$$

d'où l'on voit qu'on devra écrire

$$\frac{d}{dz}\left(\frac{dz}{dx}\right) = \frac{d^2z}{dx^2}x' + \frac{d^2z}{dxdy}y';$$

et pareillement

$$\frac{d}{dz}\left(\frac{dz}{dy}\right) = \frac{d^2z}{dxdy}x' + \frac{d^2z}{dy^2}y'.$$

D'après cela en représentant suivant l'usage, les dérivées partielles du premier ordre par p et q ; celles du second ordre par r, s, t, nous aurons pour déterminer x' et y', ces deux équations :

$$\frac{d^2f}{dx^2}x' + \frac{d^2f}{dxdy}y' + \frac{d^2f}{dxdz} + \left(\frac{d^2f}{dxdz}x' + \frac{d^2f}{dydz}y' + \frac{d^2f}{dz^2}\right)p + \frac{df}{dz}(rx' + sy') = 0,$$

$$\frac{d^2f}{dxdy}x' + \frac{d^2f}{dy^2}y' + \frac{d^2f}{dydz} + \left(\frac{d^2f}{dxdz}x' + \frac{d^2f}{dydz}y' + \frac{d^2f}{dz^2}\right)q + \frac{df}{dz}(sx' + ty') = 0,$$

et il est clair qu'en continuant de différentier par rapport à z, on formera de proche en proche, les dérivées de x et y jusqu'à un ordre quelconque $n-1$, avec cette circonstance que les dérivées partielles de z jusqu'à l'ordre n seront introduites dans leurs expressions. Il en résulte qu'en les substituant dans les relations (4), (5), (6), etc., on sera conduit à un système de n équations

entre ces dérivées partielles et les quantités a, A, B, . . . L. Nous pouvons donc en y joignant celles-ci,

$$f(x, y, z, a, A, B, \ldots L)=0, \quad \frac{df}{dx}+\frac{df}{dz}p=0, \quad \frac{df}{dy}+\frac{df}{dz}q=0,$$

effectuer l'élimination du paramètre et des n fonctions arbitraires; c'est le résultat cherché qui est ainsi une équation aux différences partielles d'ordre n. Nous allons en faire l'application à deux exemples tirés de la géométrie, après avoir remarqué que les équations ci-dessus, en x' et y', jointes à la relation (4), $px'+qy'-1=0$, donnent par l'élimination de x' et y', la condition $\Delta=0$, Δ étant le déterminant du système suivant:

$$\left\{\begin{matrix} p, & \frac{df^2}{dx^2}+\frac{d^2f}{dxdz}p+\frac{df}{dz}r, & \frac{d^2f}{dxdy}+\frac{d^2f}{dxdz}q+\frac{df}{dz}s \\ q, & \frac{d^2f}{dxdy}+\frac{d^2f}{dydz}p+\frac{df}{dz}s, & \frac{d^2f}{dy^2}+\frac{d^2f}{dydz}q+\frac{df}{dz}t \\ -1, & \frac{d^2f}{dxdz}+\frac{d^2f}{dz^2}p, & \frac{d^2f}{dydz}+\frac{d^2f}{dz^2}q. \end{matrix}\right\}$$

Mais si on ajoute aux termes de la première et de la seconde colonne horizontale ceux de la troisième, multipliés d'abord par p et ensuite par q, on aura plus simplement $\Delta=B^2-cl$ en posant:

$$cl=\left(\frac{d^2f}{dx^2}, \frac{d^2f}{dxdz}, \frac{d^2f}{dz^2}\right)\!\!\left(1, p\right)_2+\frac{df}{dz}r,$$

$$C=\left(\frac{d^2f}{dy^2}, \frac{d^2f}{dydz}, \frac{d^2f}{dz^2}\right)\!\!\left(1, q\right)_2+\frac{df}{dz}t,$$

$$B=\frac{d^2f}{dxdy}+\frac{d^2f}{dydz}p+\frac{d^2f}{dxdz}q+\frac{d^2f}{dz^2}pq+\frac{df}{dz}s.$$

Ce résultat peut s'obtenir directement d'une manière très-facile ; je me bornerai à en faire l'application d'abord aux surfaces développables enveloppe des positions d'un plan mobile: $z+\alpha x+Ay+B=0$, ce qui donne immédiatement $A=r$, $B=s$, $C=t$ d'où par conséquent l'équation si connue: $s^2-rt=0$. Soit en second lieu les surfaces canaux, enveloppe des positions d'une sphère de rayon constant,

$$(x-A)^2+(y-B)^2+(z-a)=a^2,$$

dont le centre décrit une courbe quelconque. On obtient alors

$$\tfrac{1}{2}A=1+p^2+(z-a)r, \quad \tfrac{1}{2}B=pq+(z-a)s, \quad \tfrac{1}{2}C=1+q^2+(z-a)t,$$

et le paramètre s'élimine au moyen des relations

$$x-A+(z-a)p=0, \quad y-B+(z-a)q=0,$$

qui donnent en substituant dans l'équation de la sphère,

$$z-a=\frac{a}{\sqrt{1+p^2+q^2}}.$$

De là résulte l'équation aux différences partielles du second ordre:

$$a^2(s^2-rt)-a\left[(1+q^2)r-2pqs+(1+p^2)t\right]\sqrt{1+p^2+q^2}+(1+p^2+q^2)^2=0.$$

Nous ne nous sommes occupés jusqu'ici de la formation des équations aux différences partielles que dans le cas d'une fonction de deux variables.

Considérons maintenant par exemple une fonction u de x, y, z, en la définissant par ces trois équations, où entrent deux paramètres α, β, et un nombre quelconque n de fonctions arbitraires A, B. . . . L, de ces paramètres, savoir:

$$\phi\,(x, y, z, u, \alpha, \beta, A, B, \ldots L)=0,$$
$$\psi\,(x, y, z, u, \alpha, \beta, A, B, \ldots L)=0,$$
$$\theta\,(x, y, z, u, \alpha, \beta, A, B, \ldots L)=0.$$

L'élimination des fonctions arbitraires s'effectuera par la même méthode que précédemment, et donnera pour résultat une équation aux différences partielles d'ordre n. La même conclusion s'obtiendra aussi en considérant les relations:

$$f(x, y, z, u, \alpha, \beta, A, B, \ldots L)=0, \quad \frac{df}{d\alpha}=0, \quad \frac{df}{d\beta}=0.$$

Mais elle n'a plus lieu, si l'on pose seulement deux équations avec un seul paramètre variable, savoir:

$$\phi(x, y, z, u, \alpha, A, B, \ldots L)=0, \quad \psi(x, y, z, u, \alpha, A, B, \ldots L)=0;$$

car alors on peut former une équation aux différences partielles d'ordre n, représentant le résultat de l'élimination d'un nombre de fonctions arbitraires de α supérieur à n, et égal à $\frac{n(n-1)}{2}$. Lorsque le nombre des quantités A, B, . . . L n'est point compris dans cette formule, s'il est égal à 4 par exemple, de sorte qu'on ne puisse pas obtenir une équation aux dérivées partielles du second ordre, on parviendra en introduisant les dérivées du troisième ordre, à plusieurs relations distinctes au lieu d'une seule. Cette circonstance que présente souvent l'élimination des fonctions arbitraires, montre qu'on doit attacher une grande importance aux formes analytiques où l'élimination donne lieu à une conclusion précise, à une seule et unique équation aux différences partielles; et tel a été le motif qui m'a fait entreprendre ces recherches dont je prie l'Association Britannique de vouloir bien agréer l'hommage.

Report on the Discovery of Fossils in certain remote parts of the North-western Highlands. By William Jolly.

A limestone runs from Durness and Loch Eribol, in the north of Sutherland, with varying thickness but more or less continuity south by Loch More, Inchnadamph, Ullapool, and Loch Maree, to Kishorn near Loch Carron, where it dies out on the mainland. This limestone rests on a thick deposit of quartzite, and this again on the red sandstone of the west coast. All of these rocks enter into some of the grandest scenery of the North-western Highlands.

These rocks were considered unfossiliferous till 1855, when Mr. Peach made his great discovery of those fossils in the Durness limestone which were classed by Mr. Salter as Silurian, and the discovery of which enabled Sir R. Murchison to complete his classification of the rocks of the N.W. of Scot-

land. These fossils were discovered in the limestone of Durness, where they are numerous, and where more have since then been found. This Durness limestone forms, geographically, an isolated basin lying to the west of the great strike of limestone which runs from Eribol to Skye. In this detached deposit only have fossils been found, with the rarest exceptions, to be named below. It is important, therefore, that organic remains should be found, if such exist, in the great line of strike, in order to determine whether this last limestone is fossiliferous or not, and also whether the Durness lime was deposited under the same or under different conditions. It was for the purpose of making diligent search along this great line of deposit, that a grant was asked and obtained last year from the Association; as also for the discovery of more perfect specimens, and, if possible, new species, from the Durness lime, in order to determine more precisely the relations these fossils bear to the Silurian and other systems, than could be made from the specimens submitted to Mr. Salter in 1858.

Since the Edinburgh Meeting last year, search has been instituted along this great strike of limestone at Durness, Loch Eribol, Inchnadamph, Elphin, and Kinlochewe, and will be made at Ullapool and Loch Kishorn. At these points, certain clergymen, teachers, and other gentlemen have kindly consented to do what they can towards the discovery of fossils, so that more systematic search will now be made than heretofore. Good results may be anticipated, if not in the discovery of fossils, at least in greater certainty as to the presence or absence of organic remains in these remarkable rocks.

At Durness, in July of last year, many fine fossils were obtained, through the efforts of some members of the Committee and their friends, from a remarkable island of limestone near Cape Wrath, called Ellan Garve. These fossils were shown at the Meeting in Edinburgh, and were pronounced by Mr. Peach much finer than any he had seen from the same locality. They have been secured as the nucleus of a collection for the Association. A collection of fine specimens was also made by a student resident in the district, for Professor Nicol, of Aberdeen, who now has them in his possession. This island is so difficult of access, except in the very calmest weather, that we were unable to land both this year and last. In June of this year, along with some friends, I landed on a rocky headland of limestone, on the west side of the Kyle of Durness, where fossils are exposed on the weathered surfaces of the limestone in remarkable numbers, and I obtained some good specimens. Several gentlemen in the neighbourhood have kindly agreed to make diligent search in the Durness limestone at various points, and one of them has also kindly allowed the use of his boat for this purpose; so that good work will be done at the least possible expense.

Loch Eribol.—No fossils have yet been discovered in the extensive limestone rocks on Loch Eribol. An Orthoceratite was presented to the Jermyn-Street Museum by Sir R. Murchison, which he got from Mr. Clark, of Eribol House. This Orthoceratite is unique, as being the only organism found in the quartzite. It was not, however, found *in situ*, nor at the spot marked by Sir Roderick in his paper in the 'Geological Journal' of August 1860, vol. xvi., but was picked up in a detached piece of rock between Eribol House and the loch to the west. Lime-works have been established on Loch Eribol on the limestone peninsula of Heilim, and quarrying has been done in connexion with these, but as yet no fossils have been found. These operations afford an unwonted opportunity for their discovery, and the strictest watch is to be kept by the lessee.

Inchnadamph.—In the immense development of limestone at the head of

Loch Assynt no fossil has yet been discovered, except two by Mr. Peach in the stinking limestone above the manse near Inchnadamph. One of these was an Orthoceratite. I spent some time on this limestone this year, but was unsuccessful, except in finding a piece that may turn out to be organic. Mr. Peach's discovery shows that fossils may be found here; and the parish teacher is to make search during next year.

ELPHIN is situated not far from the splendid limestone-cliff of Craig-an-Knockan, figured by both Murchison and Nicol in their papers on these rocks. Here the limestone is largely developed, and has been quarried at various points. The teacher of the Society school is to look for fossils.

Near ULLAPOOL, on Loch Broom, there has been a good deal of quarrying for lime-burning, and the sections are extensive. Something may be discovered there. Search will be made.

At KINLOCHEWE, at the head of Loch Maree, there is not so much limestone exposed as in other parts. The Free Church teacher there is to devote his spare time to a search; but much cannot be looked for, as the limestone is in contact with igneous rocks, in Glen Logan, where it is found.

At LOCH KISHORN there is a large exposure of limestone along the loch near Courthill. This will be submitted to careful search.

In this way the whole line of strike of this limestone from N. to S. will be examined by intelligent men, who have kindly and earnestly entered into the work, and we consider ourselves fortunate in having secured such cooperation. The Committee confidently hope that by next Meeting they will be enabled to present to the Association a good collection of organic remains from these interesting rocks; or, at least, to have done something that will contribute to greater certainty as to whether, and to what extent, these rocks are fossiliferous or not.

Report of the Committee on Earthquakes in Scotland. The Committee consists of Dr. BRYCE, *F.G.S.*, Sir W. THOMSON, *F.R.S.*, D. MILNE-HOME, *F.R.S.E.*, *and* J. BROUGH.

As Convener of the Committee on Earthquakes in Scotland, I have to report that the last year has passed without any incident coming within the scope of this inquiry; there has not occurred any sensible disturbance in the Comrie district, or oscillation of the lakes in the neighbourhood, such as those recorded in former Reports. In other parts of Scotland the same freedom from earthquake-movements has prevailed. But this state of quiescence is not likely to continue; and the attention of the Committee has been turned to the remedying of those defects which from time to time are apt to occur with instruments long in use, and to the extension of the means of observing to other localities suitably placed for the purpose. The accomplishment of this object renders necessary some more simple means of noting shocks than any which have hitherto been applied by the Committee. The seismometer belonging to the Association, which now occupies the tower of the parish church of Comrie, is of too complex construction, and takes up too much room, to be applicable except in a few peculiar localities. Some simple and cheap method of indicating earthquake-movements is thus much to be desired. Any apparatus for the purpose

should occupy small space, be little liable to derangement, capable of being put up in any ordinary apartment not of special construction, and its indications such as any intelligent person could easily interpret and readily note. The Committee are now anxiously considering what instrumental means will best combine these several requisites and advantages, and what stations would be most suitable to select in extending the area of the inquiry. Meanwhile the seismometer of the Association, which is the invention of the late Principal Forbes, is kept in proper working order at Comrie, where also the first supplemental indicator will be set up. Principal Forbes's son, Mr. Geo. Forbes, Edinburgh, who has gained some practical acquaintance with earthquake instruments at Naples, has been taken into their counsels by the Committee, and they have now to request that Mr. Forbes be added to their number.

(Signed) James Bryce, M.A., LL.D., *Convener*.

P.S.—During the Session of the Association at Brighton an earthquake of considerable severity occurred in the Comrie district, of which an account will be given next year.—J. B.

Fourth Report of the Committee appointed to investigate the Structure of Carboniferous-Limestone Corals. The Committee consists of James Thomson, *F.G.S., and* Professor Harkness, *F.R.S.*

At the Liverpool Meeting of the British Association the Committee reported that they hoped, by means of a new process, to produce representations of the most delicate internal structures of corals of the Carboniferous series. The necessity of such a process forced itself on the Committee by the circumstance that none of the existing methods of representing corals reproduced faithfully the details of their internal structure.

The photographs of the Carboniferous corals exhibited at the Liverpool Meeting represented these details in some of their most delicate forms. This result had been obtained by the transmission of light through their sections; and subsequent investigations have led us to infer that there are no better means than that of photography for reproducing generic details. Great expense, however, attends this process; and as it is also a very slow one, experiments have been made in order that the same satisfactory result might be more readily and less expensively obtained.

At the Edinburgh Meeting they were unable to lay before Section C the same number of results as at the previous Meeting; but they had so far succeeded as to be able to produce two plates, although they were not so perfect as was desirable: they were, however, sufficiently successful to justify the Committee in asserting that a more simple and less expensive process was available. In the application of this process the Committee have been ably assisted by Mr. Reckie, the artist employed by them in engraving the copper-plates.

During the past year the investigations of the Committee have been continued with increasing interest. They have now made sections of upwards of 1300 specimens, and have been able to add considerably to this branch of Palæontology.

In their Report presented to the Liverpool Meeting ninety-two forms were alluded to; and these presented characters sufficiently distinct to justify the

Committee in adding them to those previously described by MM. Milne-Edwards and Jules Haime. By this addition, the number of British Carboniferous corals amounts to 156 species.

From the forms which have been recently sliced, and also from those of former years, the Committee have ascertained that among these species from 300 to 400 varieties occur, an increase which is so great, and the variations so minute, that it becomes difficult to determine specific characters among these corals.

The gradations of the varieties are in some cases so constant, and pass so imperceptibly into each other, that they induce the inference that there has been an inherent tendency in the polyp to vary independent of, but to be modified by, the conditions of its surroundings.

The forms occurring in deposits which have resulted from deep water are not only more symmetrical in outline, but also more perfect in their internal structure than such as are met with in strata formed in shallow water, where they have been exposed to the constant shiftings and abrading influence of shore deposits.

In the case of such forms as occur in a matrix originally in the state of fine mud, these are small in size; and they seem to have been gradually exterminated by the impurity of the water, arising from the increase of the fine sedimentary matter originally held in suspension.

Many of the specimens which have been sliced are found to be perfectly useless from their imperfect state of fossilization. Some reveal structural characters not previously noticed by authors in this branch of Palæontology; it is desirable that these should be studied further before a complete classification of this group of animal life is attempted.

The classification of corals has in some instances been based upon external aspects; in others on the number and form of the septa. The number and arrangement of the lamellæ which pass from the inner margin of the primary septa and fill up the columellarian space have also been adopted as bases of classification.

Some writers regard the form and position of the dissepiments of the endotheca as of specific importance; and some rest generic and specific distinctions upon the presence or absence of the columellarian line which passes from the inferior to the superior, and terminates in the centre of the calice. Observations, however, justify us in inferring that, although these several characters are of importance, they cannot be depended upon for specific determinations.

During the last fifteen years no less than 10,000 specimens have been sliced, many of which show structural differences in character from such as have been accepted as of specific importance, which induce us to conclude that further examinations are necessary before determining even a variety.

It has been stated that the columellarian line has been accepted as of generic value. In a new group of corals, which will form the subject of an extensive memoir, this line is developed, in some instances, near the inferior, and in others it occurs only in the superior portion of the coral.

The dissepiments filling up the interseptal space are in some forms angular, in others subangular and rectangular. We have, however, recognized these several outlines in the same form, and cannot, therefore, accept the outline of the dissepiments as of specific importance.

In the case of the number of lamellæ also, some forms present the lamellæ in one part, while in another part of the same coral the space is filled up by tubulæ.

Concerning the number of the septa, this can hardly be regarded as of value, since this number is dependent on age and surrounding conditions during the growth of the polyp.

In order that some definite rule may be obtained as a guide in the classification of corals, it is proposed to select generic types, and, after making sections of these through different parts, to exhibit their structure in plates, from the ova to their mature forms; and it is only when this is faithfully done that we can hope to determine where a species begins and a variety ends.

We have, in conclusion, to thank the British Association and many kind friends for the assistance rendered us, and hope for its continuance until this laborious but interesting investigation be completed, as we are satisfied that results will be obtained commensurate with the time and expense which the work has cost during the last fifteen years.

A sum considerably in excess of the grant having been expended, the Committee have to ask that a further grant of £25 be placed at their disposal for continuing the investigation.

Report of the Committee, consisting of J. F. BATEMAN, *C.E., F.R.S.,* P. LE NEVE FOSTER, *M.A.,* C. W. MERRIFIELD, *F.R.S.,* E. EASTON, *F.G.S.,* F. J. BRAMWELL, *C.E.,* W. HOPE, *V.C., and* H. BAUERMAN, *F.G.S., appointed to consider the mode in which new Inventions and Claims for Reward in respect of adopted Inventions are examined and dealt with by the different Departments of Government, and to report on the best means of removing any real causes of dissatisfaction, as well as of silencing unfounded complaints.*

HAVING regard to the evidence taken by the Committee of the House of Commons on the subject of the Patent Laws, in 1871 and 1872, on the relations between inventors and the Government, as well as to complaints made in Parliament and elsewhere, your Committee were of opinion that they had before them sufficient information "as to the mode in which new inventions, and claims for reward in respect of adopted inventions, are examined and dealt with by the different departments of Government." They therefore did not think it necessary or desirable to examine witnesses on the subject.

The Committee considered it fully established that the present methodical mode of dealing with inventions submitted to the different departments of Government was uncertain and unsatisfactory in itself, frequently unjust to inventors, and generally detrimental to the public administration. They considered it established to their satisfaction, that real injustice was frequently done to inventors, not only by neglect and procrastination in dealing with their claims, but also by the undue preference of other conflicting claims urged by officers of the different departments. Without entering into the merits of any cases in point, it appeared beyond doubt that the practical judges of the inventions have been very often rival inventors within the departments. The Committee considered it obvious that this placed both the inventor and departmental officers in a false position, and that the consequent decisions could be satisfactory to nobody. As matter of evidence, they considered that these departmental decisions had failed to give satisfaction either to inventors or to the public.

It remained for the Committee to consider and report on the best means of removing "any real causes of dissatisfaction, as well as of silencing unfounded complaints."

The Committee are of opinion that the primary means of effecting this object is to bring the adjudication of these claims within a jurisdiction independent of the administration of departments of the public service. As long as the Patent Law remains as at present, the Committee are of opinion that the only satisfactory method of determining what compensation should be given to inventors, in cases where the Government makes use of their inventions, is to have recourse to arbitration. Any inventor whose patented invention is used, or believed to be used, by any Government official, or agent under Government authority, should be at liberty to apply to the proper Government department, stating what is the invention used, and how and where, and requesting that the application be referred to the decision of two arbitrators, who shall be appointed, one by the applicant and one by the Government department, with power to appoint an umpire, and that the proceedings be assimilated to ordinary compensation cases.

The Committee, hoping that the recommendations of the House of Commons Committee will, at an early period, be made the subject of legislation, recommend that steps be taken, by petition to Her Majesty or otherwise, to make the grant of Royal Letters Patent for inventions of effect as regards the servants and officers of the Crown in the same way, and to the same extent, as Letters Patent are of effect as regards all others of Her Majesty's subjects.

Your Committee feel that, if in every case officials appointed to investigate new inventions were required to affix their signatures to their reports, very beneficial results would follow, as the personal responsibility thus attaching to them would ensure their full attention, and deter them from rejecting hastily, or on insufficient grounds, any proposition or invention brought before them.

The Committee consider that their Report would be incomplete if they did not call attention to an Act for preserving secrecy in the case of inventions connected with warfare.

This Act is the 22nd Vic., cap. 13. Its principal provisions are:—

Section 1. Improvements in instruments or munitions of war may be assigned by inventors to Secretary of State for War.

Section 2. Foregoing enactment may extend to assignments already made.

Section 3. Secretary of State for War may certify to Commissioners of Patents that the invention should be kept secret.

Section 4. Where he so certifies, petition for letters patent to be left with Clerk of Patents, under seal of Secretary of State.

Section 5. Such packet to be kept sealed.

Section 6. To be delivered on demand to Secretary of State or Lord Chancellor.

Section 7. At expiration of patent to be delivered to Secretary of State.

Section 8. Where Secretary of State certifies after filing of petition, documents already filed to be put into sealed packet.

Section 9. Copy *not* to be sent to Scotland or Ireland, nor published, but otherwise provisions of Patent Acts to apply.

Section 10. No *scire facias* to be brought.

Section 11. Secretary of State may waive benefit of Act.

Section 12. Communication of invention to Secretary of State not to prejudice letters patent.

Report of the Committee for discussing Observations of Lunar Objects suspected of Change. The Committee consists of the Rev. T. W. Webb, *the* Rev. Robert Harley, *F.R.S., and* Edward Crossley, *Secretary.*

The Committee have pleasure in presenting their Second Report on the above subject. It will be remembered that the Report of last year was confined principally to the discussion of the possible variations of visibility of the numerous spots and craterlets upon the floor of Plato under the same conditions of illumination. That now presented is directed chiefly to the discussion of the various streaks and bright patches which interlace the spots and craterlets.

One interesting and important change has been fairly shown—the floor of Plato becomes darker with the increase of the sun's altitude. Mr. Birt has suggested an explanation of this phenomenon. Whatever be the true cause of this change, it is very difficult to account for it by the ordinary laws of reflection. When we consider the varying aspect of the streaks at the same time of the luni-solar day, we cannot but think that, with careful observations made with powerful instruments, such as the Newall Refractor and many others, we may be able to confirm or otherwise a physical explanation of these curious changes involving the existence of certain gases and vapours upon the surface of the moon.

The Committee can only look upon the study of Lunar Physics as in its infancy, and they trust that in future years the Association will not overlook this important branch of astronomical inquiry.

Report on the Discussion of Observations of Streaks on the Surface of the Lunar Crater Plato. By W. R. Birt.

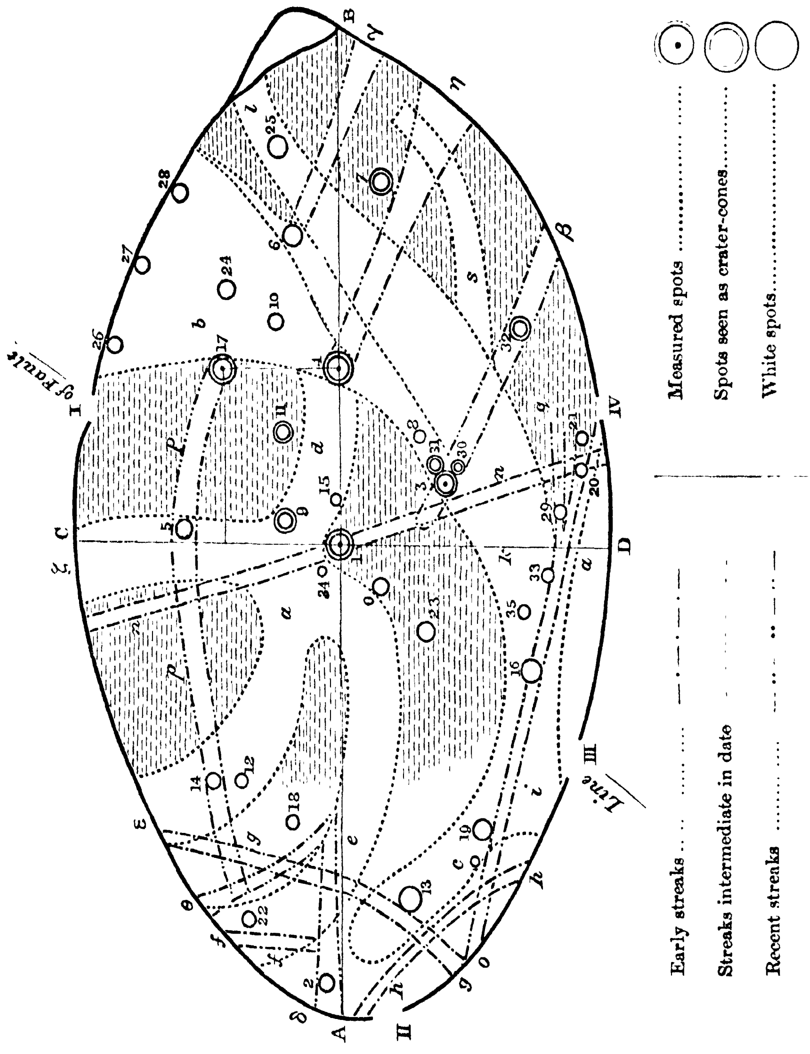
In completing the task assigned to me of discussing the observations of the streaks on the floor of Plato, I have been desirous of including every, even the most minute, circumstance bearing on the exhibition of phenomena that may possibly illustrate the condition of a small portion of the moon's surface at the epoch 1869 April to 1871 April. Drawing my conclusions from the experience of twelve years, I feel that I may confidently say it will be some years before another series of observations of a particular region will be undertaken with the view of so closely examining the spots and streaks characterizing it, unless a staff of efficient observers be organized with the provision of a fund sufficiently ample to defray all the necessary expenses. The work is a difficult one. The staff should consist of not less than six devoted observers, who would, independently and most probably, as in the present case, work with instruments of varying aperture and carefully record all their observations. The principal qualification is a keen eye for the appreciation of delicate variations of tint, and the detection of minute spots of light with a readiness of referring them by estimation and alignment to the respective localities of the region on which they are seen. The observations should not be allowed to accumulate, but should be forwarded at once to an experienced selenographer charged with the work of arranging and discussing them. Taking into consideration the results of the discussion of the present and previous years embodied in the two Reports, it appears that in order to confirm these results, and to open up new investigations in other regions of the moon's surface, the requisite time cannot well be fixed at less than three years—five would most probably afford the best results.

The results of the present work may be briefly characterized as confirming, by a direct reference to the sun's altitude above the horizon of Plato, the supposition that variations of tint in some measure depend on increasing and decreasing altitudes. The ascending and descending branches of the curve obtained from independent estimations of tint by the several observers are sufficiently near those of the sun's altitude to enable me to delineate a normal curve representative of the sun's influence in darkening the floor of Plato, or else in overspreading it with something of the nature of a dark covering, as his rays strike the surface at the increased angle of about 40 degrees. While this darkening influence comes out most unmistakably, there are variations in the lighter and darker portions of the floor which seem quite irreconcileable with solar influence of a gradual character. The treatment of the observations under intervals of the luni-solar day fails to bring out any regularity in these variations, and it is only by treating the observations *chronologically* that the true sequence of the changes can be detected. To do this for every separate streak would not only swell this Report to an unseemly length, but would consume more time than can be devoted to the inquiry. I have, nevertheless, considered separately the changes which were observed in August 1869; and in order to assist in showing more distinctly these changes and their connexion *inter se,* I have introduced the *hypothesis* of a dark obscuring medium. Not that I lay any stress upon a mere hypothesis of this kind; it serves to connect the observations, and that is all; it may or it may not be true, and should therefore be held very lightly. In addition to this examination of the distribution of the light and dark spaces on the floor, I have traced from day to day the appearances of a single streak, that designated α, from its first detection in September 1869 to the close of the observations; and to show more conclusively that the variations manifested by this and neighbouring streaks were not dependent upon the same solar influences which contributed to the darkening of the floor, I have arranged all the observations bearing upon them in the order of intervals of the luni-solar day. The principal divisions of the present Report are:—1, the influence of the sun on the floor of Plato; 2, an examination of changes recorded in August 1869; 3, the history of streak α; and 4, observers' notes arranged in intervals of the luni-solar day, and embodying generally the results of the two years' observations.

It may contribute to a better understanding of the nature of the streaks, their connexion with the spots, and their variability, if the physical characteristics of Plato be described. We have:—*First*, a mountain-cinctured plain, of about sixty miles in diameter, the wall rising to the average height of nearly 4000 English feet. This wall is surmounted at four points by needle-like pinnacles of rock, which rise to a further elevation of 3000 feet, so that their summits attain the height of about 7000 feet above the plain, which is not strictly level, the border having suffered from dislocation, which has raised the floor in a direction from S.E. to N.W. *Second*, two systems of streaks, as seen between April 1869 and April 1871. They are related to the "fault" produced by dislocation. The S.W. system consists of the "trident," the N.E. of the streaks β, η, and γ (see fig. 1). These two systems, which are opposite in direction, are intimately connected with certain spots in their respective neighbourhoods, the S.W. radiating from spot No. 1. Of the N.E. system, streak β emanates from spot No. 3, η from spot No. 4, and γ from spot No. 6. The most prominent streak on the floor is the sector which takes its rise from spot No. 4, but has occasionally been seen in the opposite direction, extending as far as spot No. 3. The S.E. portion, that extending to the

S.E. border from spot No. 4, has, under very favourable circumstances, been seen by two independent observers at two different epochs as separate streaks radiating from spot No. 4 (see fig. 15, p. 285). *Third*, the N.W. portion of Plato, containing spots Nos. 13, 19, 16, 33, and 35, and characterized during the period of the observations by greater alternations of brightness and changes in the forms of the streaks than obtained on any other part of the floor.

Fig. 1.



Enumeration of Streaks.

South-west area. System S.W. of the fault crossing Plato.

α. The trident, very rarely seen complete (see figs. 5, p. 252, 6 and 7, p. 254)

ζ. The S.E. arm of trident, its apparent origin spot No. 1.

ϵ. The central arm of trident, apparent origin spot No. 1.
e. The N.W. arm of trident, apparent origin spot No. 1.
θ. The narrow streak forming the S.E. bifurcation in the neighbourhood of the N.W. arm of the trident.
δ. The N.W. bifurcation in the same locality, a narrow streak.

South area. S.W. of the fault crossing Plato.

p. A streak parallel with the south border. It was first seen by Mr. Pratt on May 13, 1870. See Report British Association, 1871, pp. 88–91; also History of Streak a, concluding paragraph, *post*, p. 267.

South-east area. N.E. of the fault crossing Plato.

b. The sector originating at spot No. 4, of a furrowed character, as seen under the most favourable circumstances.
l. A branch from the east side of the sector, running towards the south-east.

North-east area. System N.E. of the fault crossing Plato.

β. The streak emanating from spot No. 3.
η. The streak emanating from spot No. 4.
γ. The streak emanating from spot No. 6.
d. The stem of the trident, its apparent origin spot No. 1. It is but rarely seen.
s. A curved streak seen by Mr. Pratt on August 28, 1869.

North area. N.E. of the fault crossing Plato.

κ. A slightly curved streak east of spot No. 16; its northern portion is coincident with a.
a. The straight streak east of Webb's Elbow.
q. A branch from κ crossing the locality of n, seen only by Mr. Pratt, August 28, 1869.

North-west area. S.W. of the streak crossing Plato.

λ. A straight streak nearly aligning with β (see fig. 16, p. 286).
μ. A shorter streak parallel with λ (see fig. 16, p. 286).
c. A curved streak directed towards the N.W. arm of trident.
o. The continuation of a, west of Webb's Elbow.
i. Webb's Elbow (see fig. 1, p. 247).
ν. A short streak parallel with Webb's Elbow, seen once only (see fig. 16, p. 286).

Streaks but rarely seen.

f. A short streak on the west part of the floor, seen by Elger in 1866.
g. A long streak on the west part of the floor, seen by Birt in 1863.
h. A short streak on the N.W. part of the floor, seen by Elger in 1866. The north-eastern part would seem to be a continuation of f.
n. A streak crossing the floor from N.N.E. to S.S.W, through spot No. 1, seen by Birt in 1860 and 1863, also by Pratt on April 12, 1870, and March 3, 1871 (see *post*, pp. 281 and 282). Both in interval 96 to 108 hours.

The above enumeration has been drawn up with an especial view to the connexion existing between the spots and streaks. There are a few points worth notice, particularly as regards the streaks: one is, their appearing brightest nearest the border of Plato; another, assuming that they have

their origin in spots, that they extend from higher to lower ground; and a third, their sharp and definite character on some occasions contrasted with their extreme delicacy on others. Mr. Pratt, under date of November 9, 1869, wrote as follows:—"As far as I can remember, I have always forgotten to say *how* delicate the chief parts of the trident are; they are most delicate." In the Observers' Notes (see *post*, pp. 272 to 298) there are numerous instances recorded of the difficulty of detecting the stem and arms of the trident in the neighbourhood of spot No. 1, and often of their complete disappearance. On the other hand, observers frequently speak of the sharp definition of certain streaks. As regards the connexion between the spots and streaks, in the case of the largest spot, No. 1, which is situated on the highest part of the floor, it appears highly probable that the three arms and stem of the trident are connected with it much in the same way as streams of lava are connected with the volcanic orifice from which they issue; the varying intensity of brightness of the arms is greatly in accordance with the supposition of their being the results of intermittent emanations from an orifice of this kind, of which the cone is spot No 1. The spot ranking next to No. 1 is No. 4, which appears to be of almost the same character as No. 1, the main difference being its frequent *hazy* appearance, which on some occasions is very marked. From this spot three distinct streams appear to issue:—*First*, the sector, which is usually seen to spread out from it in a fan-shape; very rarely the fan of brightness has been seen striped, as if the slope from spot No. 4 to the S.E. border were furrowed. Generally the brightness extends as far as the border, where three spots have been (although rarely) seen; and on one occasion a dark space, as if occasioned by a cloud, covered them. *Second*, the streak η, extending to the N.E. border: this streak very frequently exhibits, in common with the arms of the trident, a fading of the portion between the cone and the border, so that the portion near the border is usually the brightest. *Third*, a streak mentioned only as an extension of the sector from spot No. 4 to spot No. 3; it is not often seen. The disposition of the three streams indicates very probably the *channels* in which any ejecta may have descended from the orifice, and in which such ejecta may have so accumulated as to have produced the appearance of "spurs" noticed by Mr. Pratt (see Report Brit. Assoc. 1871, p. 95). On either side N.W. and S.E. of spot No. 4 are the spots Nos. 3 and 6. The three are situated upon the N.E. slope from the "fault," and from No. 3 (which, by the way, is a group of three openings) issues the streak β, and from No. 6 the streak γ. The near parallelism of the streaks β, η, and γ results most probably from the positions which the spots from which they issue occupy on the sloping ground.

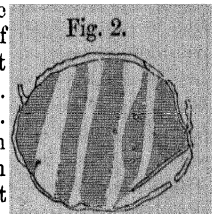
The north-west part of the floor offers a very decided contrast to every other portion, characterized, as it has been during the two years, by considerable alternations of brightness, as well as alterations in the forms of the streaks found upon it. The connexion between the spots and streaks, to which attention has been directed, is well marked; but here in the N.W. area it is difficult to detect such a connexion, if it exists. The principal spots are Nos. 13, 19, and 16; and these lie in the principal streak of the district, and do not appear as orifices from which distinct streaks issue. In whatever the peculiarity of this portion of Plato consists, it is one that should be most assiduously watched and every phenomenon witnessed on it most carefully recorded.

The observations had proceeded with great care during a period of more than twelve months, when a new streak made its appearance between spots

Nos. 5 and 14. Some months afterwards a continuation of this streak eastward of No. 5 was observed, and very lately it has been seen between Nos. 14 and 22 (*p*, fig. 1, on p. 247). A very remarkable characteristic of this streak is its parallelism with the south border. Taking all the circumstances of the observations into account, it can scarcely be doubted that this is a *new* streak, the eastern and western portions being connected with spot No. 5, and the further continuation westward with spot No. 22.

If it should be well established that new streaks make their appearance from time to time, we may be able to understand that many recorded differences from the older delineations are to be referred not so much to errors of the earlier selenographers, as to real changes in the objects themselves; for example, this very area of Plato is figured by Beer and Mädler, in the first edition of the large map, as being crossed from N. to S. by *four* light streaks, as in the annexed sketch, fig. 2. That Mädler actually saw these four streaks there can be little doubt, as they are distinctly mentioned in 'Der Mond.' That they are not in existence at present is quite certain; for the disposition of the streaks is now very different from that figured by Beer and Mädler.

Fig. 2.



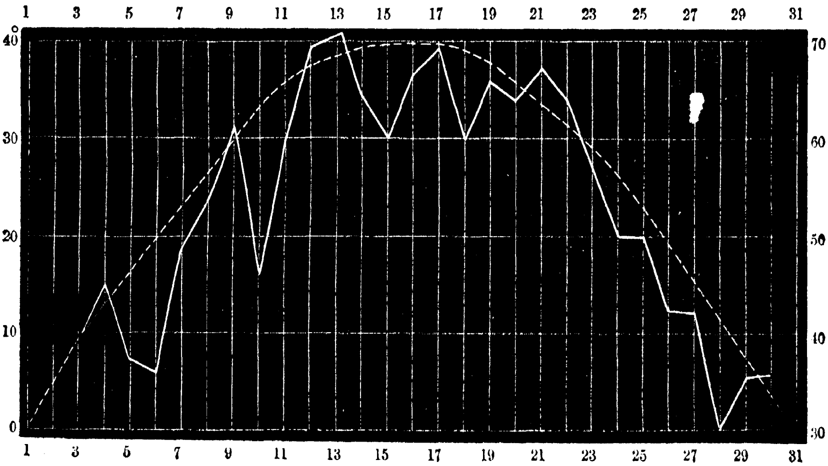
Plato.—Beer and Mädler.

I.

INFLUENCE OF THE SUN ON THE FLOOR OF PLATO.

Previous to an examination of certain non-periodic changes of brightness, colour, and the forms of streaks, it is essential to ascertain the normal variations of tint as dependent upon the gradual increase and decrease of the sun's altitude before and after the sun's meridian passage. This has been ascertained by noting the tint of the floor in accordance with the directions specified on the form for receiving the records of the observations. A medium tint has been regarded as the mean line, and its value fixed at 0·50; and as the curve of the sun's altitude consists of an ascending and a descending

Fig. 3.



Curve of variation of tint on the floor of Plato.

branch, and also as the floor becomes darker as the sun ascends higher, an ordinary light tint has been fixed at 0·33, and a dark tint at 0·66; very light and very light indeed have been registered provisionally lower than 0·33, and very dark and very dark indeed higher than 0·66, so as to give a range, as regards Plato, of 1·00. The actual range resulting from 133 observations in two years is 0·41, and the range of solar altitude at the equinoxes on the parallel of 50° is 40°. The chromatic range very nearly coincides with that of altitude, and the connexion between the tint of the floor and the effect either of light or heat is plain and unmistakable. The floor must therefore consist of material capable of becoming darker by exposure to light and heat, or it must possess a covering that may possibly be affected in the same way. The inflexions of the chromatic curve indicate rather considerable variability, especially in the deepening of the tint, which hardly accords with a *permanent* surface being heated by definite and regular increments of heat: and it would also appear that the solar effect is not fully attained; for although the ranges of both curves are very nearly equal, a mean chromatic curve drawn with a free hand would indicate an average *lighter* floor than that which a regular heating might be expected to produce. So far as the writer is aware, this is the first attempt to indicate *numerically* the chromatic effect of light or heat, or both, upon the moon's surface. It has long been known that the grey plains appear darkest under a high sun, but the knowledge of the nature of the progression has been vague and undefined. It is greatly to be desired that other spots, especially in lower latitudes, should be observed in the same way; but some time must necessarily elapse before observations of them could be compared with those of Plato.

II.

An Examination of Changes recorded in August 1869.

These changes were recorded in four carefully executed drawings of the floor of Plato by Mr. Pratt. They exhibit, first, a rapid alteration of the distribution of the light and dark portions of the floor between the 16th and 17th of August, and a more gradual but slight, yet still perceptible, change from the 17th to the 28th. Calling the figures in their order 4, 5, 6, and 7, and starting with the assumption that the permanent colour of the floor is *light* (see Section on the influence of the sun on the floor of Plato), we may trace the changes between each of the observations, remarking at the outset that the spots are presumed to be permanent as to their positions on the floor.

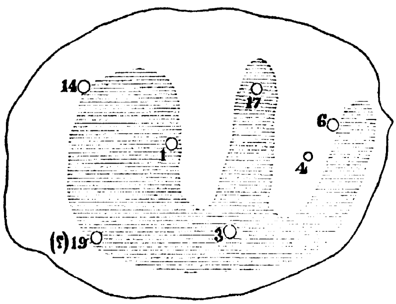
Fig. 4, August 16, 1869, exhibits a disposition of the darker shading *entirely detached from the border on every side*. The shape is roughly that of a W,—the western leg being the widest, with spots Nos. 14, 1, and 19 just on its border; the dark space forming the middle leg extending from beyond No. 17 to beyond No. 3, both spots being involved in it; and the eastern leg very near the east border, having spot No. 6 on its western edge. Seven spots are given on the drawing, viz. Nos. 14, 1, 6, and 19, just on the border of the darker portion, Nos. 3 and 17 in its midst, and No. 4 on the light portion.

Theorizing merely as a help to connect and interpret the phenomena observed, and assuming that the lighter tint is that of the floor and the dark tint that of a something which varies in position, the nature of which we have yet to learn, we have in fig. 4 its disposition on August 16, 1869. Of the shading of the floor on this day Mr. Pratt thus writes:—" This was more

curious than I had seen it before, and totally different from my former sketches."

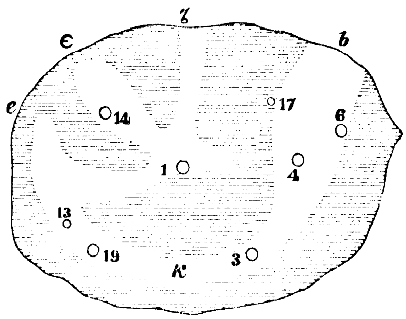
Fig. 5, August 17, 1869.—In this figure we see a very considerable *extension* of the dark portion of the floor, the spot No. 6 still marking the position

Fig. 4.



Plato, 1869, August 16.—H. Pratt.

Fig. 5.



Plato, 1869, August 17.—H. Pratt.

of the western edge of the eastern leg of the W of the 16th. On the 17th we find this leg had extended quite to the eastern border; indeed the whole of the northern boundary of the dark portion had become extended to the N., N.W., and W. border; at the same time the opening between the eastern and middle legs unveiling the lighter floor (?) had become extended, so as to include spots Nos. 3 and 19, and to exhibit (?) spot No. 13. If this were so, it could only have been effected by a *separation* of the darker substance, whatever it was, which, spreading outwards towards the border of Plato, produced the different configuration observed on the 17th. This opening from the S.W. part of the floor to the east border and sector was seen by Mr. Gledhill on September 25, 1869 (see *post*, p. 295, and fig. 9, p. 263).

In the southern part of the floor we have another opening, apparently in the neighbourhood of spot No. 1, which joined the opening effected in the northern part at its western end, the N.W. arm of trident *e*; and, simultaneously with this opening, the dark substance near spot No. 3 overspread a portion of the opening between the western and middle legs, by which the stem and north-western arm of the trident was produced.

That part of the darker portion just S.W. of spot No. 1 must have undergone the greatest change in its disposition, inasmuch as not only was an opening made from No. 1 to beyond No. 14, but the substance itself must have increased; for there can be no doubt that the area covered by the darker portion on the 17th exceeded that covered on the 16th. The effect of this extension was the production of the S.E. and middle arms of the trident, or, at least, the rendering of them apparent as compared with the 16th.

Looking at the position of spot No. 1 in connexion with the three arms of the trident, can it be possible that emanations from this crater tended to preserve the radiating openings marked by the figure so well observed from the 17th to the 28th inclusive?

In reference to August 17, Mr. Pratt has the following remarks:—"This [the floor] was very remarkable: resolved to give it especial attention, and, after some application, succeeded in adding piece to piece till a sketch was

completed, very strange in comparison with last night's sketch. Its form, complicated as it was, was very carefully traced in the drawing, and repeatedly seen afterwards, but so delicate that it was impossible to see the whole at once. It required to be traced out by minute attention." Compare Mr. Pratt's drawings (figs. 5, 6, and 7) with Mr. Gledhill's of September 25 (fig. 9, *post*, p. 263).

In comparing Mr. Pratt's sketches of August 16 and 17, the transition in the 25 hours is very remarkable; indeed so much so as to indicate that some extraordinary change had come over the floor in the interim: the disposition of light and dark is almost entirely different, yet I think I can trace the effect of "action" on the floor. On the 16th the lighter portion affected the border, the darker portion being entirely separated from it. The northern boundary of the dark portion took the form of the streak *c* and *κ*, which was plainly seen on the 17th, with a dark portion on its north. Had the streak *c* and *κ* a *motion* southward from the north border between the two observations? Again, on the 17th, *e*, the N.W. arm of the trident, was not separated from *c*. It would appear that the markings, as seen on the 17th, were *evolved*, from the peculiar and remarkable disposition of the light and dark portions seen on the 16th. It will be seen further on that, as the observations proceeded, the light portion was not unfrequently noticed to be in contact with the north border.

1869, August 20.—Mr. Gledhill described the floor as darker than the surface of any of the *Maria*=0·99; the sector faint and all spots faint. On the same day Mr. Pratt thus graphically describes his seeings:—"The shading on the floor of Plato is quite a study, and a perplexing one; sometimes, when the air is disturbed, a light sector (S.E. part), like Mr. Birt's key-plan, is alone visible. Again, in a few minutes two streaks from Anaxagoras would seem to cross the floor, as sketch May 22, 1869; then, again, between the two, a third narrower streak appeared, similar to Webb's copy in 'Celestial Objects;' and as definition improved, a light marking near the north rim (*κ*) was seen; and again a change, and the appearance is decidedly the same as on the 17th of August, a near approach to Mr. Knott's sketch.

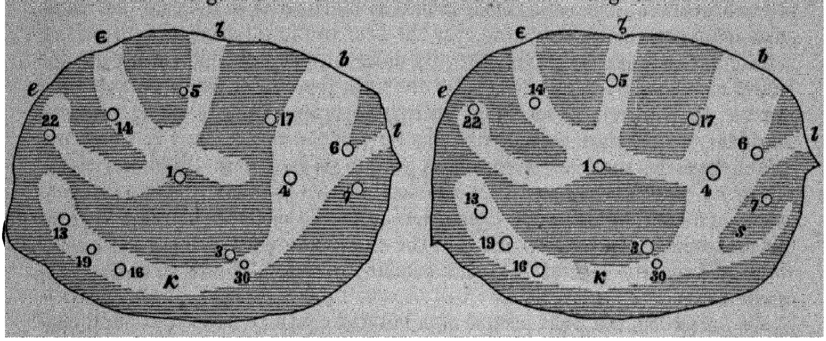
"These different appearances were reobserved, in all their curious dissolving-view-like changes, several times over, thus beautifully showing the harmony that may possibly exist between the most dissimilar observations, and strongly suggestive (to my own mind) that *the form* of the *shading* on the floor is *permanent*, and that the various degrees of visibility of its more difficult features is owing to the relative changes in the medium through which we see it—whether of the earth's atmosphere alone, or of an obscuring medium on the floor itself, must be determined by comparison with *similar* and *simultaneous* observations in different parts of the world. Thus within two hours I several times saw four greatly differing aspects of the shading on the floor, viz. B. & M.'s, Mr. Birt's, Mr. Knott's, and my own."

1869, August 21.—Mr. Gledhill recorded the tint of floor as dark as that of the Mare Crisium, and that the light sector was fairly seen.

Fig. 6, August 23, 1869.—We find in this figure the *extension* and *gathering* up of the dark portion still in progress, although to a very small extent as compared with the "action" of the 16th to 17th. The northern light portion was seen separated from the N.W. arm of the trident, and an opening made from spot No. 6 to the S.E. border, apparently by the action of the spot. Some additional spots were seen on the 23rd—viz. No. 5 on the *west* border of the S.E. arm of the trident, No. 22 on the N.W. arm, No. 16 on the northern opening, and No. 7 near the east border.

On this day (August 23) Mr. Gledhill described the bounding lines of the light sector, when produced, as cutting two craters outside and above Plato, and the sector itself as "faint, but luminous and well seen." Mr. Pratt's record is as follows:—"The floor was seen as on the 20th inst., similar to Mr. Knott's; other markings of a more complicated character were very

Fig. 6. Fig. 7.



Plato, 1869, August 23.—H. Pratt. Plato, 1869, August 28.—H. Pratt.

strongly suspected. The trident-shaped marking a little more slender and elongated N.E. and S.W. than in my sketch of the 20th inst., probably an error in drawing its first appearance. On this drawing I have the following remark:—'N.W. arm of trident separated from curved streak by a narrow neck of dark surface. The stem as on the 17th.'"

1869, August 25.—Mr. Gledhill described the floor as "not so dark as the upper part of Grimaldi."

1869, August 26.—Mr. Pratt writes: "Shading on floor visible, precisely as in sketch of the 23rd of August, 1869—viz. the long streak from the N.W. round by N. and crossing S.E., with the ray l towards the middle of II E ψ^2, and the trident-shaped marking on the S.W. part of the floor, with the streak [stem of trident, d] extending halfway from spot No. 1 to No. 4."

1869, August 27.—Mr. Gledhill described the light sector as a very faint object. Spot No. 3 easily seen double, and the floor but little darker than the Mare Imbrium.

1869, August 28.—Mr. Pratt's record is as follows:—"The shading of the floor was seen as on the 23rd of August, with *the addition* of the apparent continuation of the streak (d) from spot No. 1 to spot No. 4, and a curved streak commencing abruptly at the shadow of the rock *Rupes Smythii* (B. & M.'s ζ), not sketched, and continued towards spot No. 3, and joining the streak along the north side of the floor." These features are exhibited in fig. 7; the opening forming the stem of the trident is seen extending as far as the "Sector," and a new opening, apparently a continuation of the northern opening, extending north of spot No. 7 towards the east border.

The hypothesis suggested as an explanation of the variations depicted in Mr. Pratt's drawings recognizes the darker portion of the floor as possessing an obscuring character, and subject to changes which do not affect the lighter. Although looking at this hypothesis, as set forth in the above remarks, as *explaining* the variations observed by Mr. Pratt, yet it is difficult to divine the nature of the darker portion, as it appears to absorb light rather than reflect it. It is noteworthy that it is the darker portion of the floor that

varies its tint to the greatest extent. There are further phenomena which require explanation; neither the light nor the dark tints are seen at sunrise or sunset, but a greenish tint characterizes the floor at those times. It is when the sun attains an altitude of 30° that both the light and dark tints appear; and it has been especially noted that when the craterlets assume the appearance of white spots, the sun is usually about 30° high. All the phenomena hitherto observed on Plato, except the variations in the visibility of the spots, and, it may be, in the visibility of the streaks also, depend upon solar influence.

In order to guide future inquiry, it may probably be useful to present an enunciation of the principal features of the hypothesis employed in explaining the above-recorded variations as bearing upon the lighter and darker markings of lunar plains generally.

The hypothesis is based upon the *known* properties of gases and their affections by heat. Being well acquainted with phenomena, the proximate causes of which are understood, we may proceed to the study of other phenomena of which the *loci* are inaccessible to us, but which, being *knowable*, we may also, by observation and induction, become acquainted with their causes.

We *know* that the effect of *heat* on all bodies whatever is to *vaporize* them, and this vaporization proceeds at all temperatures, low as well as high. We also know that vapours behave as permanent gases, are diffused through them, are elastic like them, and are expanded as they are by successive increments of heat. We further *know* that vapours of even solid substances attain a state of maximum density in given volumes of gases dependent upon temperature; and our *knowledge* extends a step further, viz. that when the temperature of a given volume of gas is diminished below the point of maximum density of any particular vapour, the superabundant vapour is condensed and cloud or dew are formed, and this alike of metallic as well as of liquid substances. Now, bearing in mind these four results cognizant by us, the conclusion seems to be irresistible,—(1) that the sun shining on the moon's surface must vaporize the materials of which it is composed; (2) that the *vapours* thus raised from the surface must be dissimilar, inasmuch as the different reflective powers of different parts of the surface indicate the existence of different materials composing the surface; (3) that the different vapours resting on the solid surface act upon each other and upon the materials of the surface itself, so that diffusion takes place, and maximum densities are attained as the temperature both of the surface and of the vapours *increase*; (4) that the expansibility of the vapours raised above the surface by the accumulated heat of at least 177 hours of uninterrupted sunshine must produce *ascensional currents* of the liberated vapours, carrying them into colder regions, where condensation occurs, and cloud or mist is formed; (5) that the attraction of gravitation acting on the condensed vapours causes them to descend into warmer regions, where they are dissolved; and as the temperature declines less vapour is raised, and the features of the surface become unobscured.

A very pertinent question may here be asked. Is this hypothesis capable of substantiation, or, upon examination, is it likely to be found destitute of proof? In reply it may be asked, Do the darker markings, which appear to be formed some time after sunrise upon the floor of Plato, partake of the nature of clouds? and are these clouds perforated and separated by elastic vapours rising from a surface heated by an exposure to sunlight of 48 hours or more, in consequence of which its reflective powers become stronger, pro-

ducing the lower lighter surface? The difficulty in this supposition is the dark upper surfaces of the hypothetical clouds. If we can find a vapour which, when illuminated by the sun, appears darker than the ordinary surface of a cloud of condensed aqueous vapour in sunlight (which, by the way, shines with about the same luminous intensity as the moon's surface), we shall be in a fair way of explaining the difficulty. The green colour which is witnessed at sunrise and sunset is probably the natural colour of the floor of Plato, which, under the accumulated heat of the solar rays, reflects a lighter tint; at the same time the condensed vapour overspreads the lighter floor below, giving rise to the appearances we witness.

In applying this hypothesis to the explanation of the phenomena presented by Linné, it is necessary to remark that we have a shallow basin surrounding a cone. The earliest appearance is that of the cone standing out from the dark surface around, the next of a white spot, more or less of a cloudy character, surrounding and hiding the cone. If the above-enunciated hypothesis be correct, it would explain the Linné phenomena thus—at sunrise the features are well marked, as neither a liberation of gas nor its condensation has taken place: as the sun's altitude increases, the surface around Linné becomes heated, reflects more light, and a spot is formed at the same time in the lower levels; the condensation of liberated vapour not far above the surface produces the generally observed dark appearance of the *Mare*, obscuring on many occasions spots and craters. The remarkable instance of the contraction of the white spot around Linné in June 1867 may be explained by the condensed vapour rising higher, so as to leave a smaller area of the upper part of the cone visible; or if it were at an elevation equal to about the summit of the cone of Linné, a partial cessation of the liberation of elastic vapour would allow it to gather around the cone, to be dispersed by a further eruption of vapour or gas from the orifice of the cone.

On the 22nd of September, 1871, I received a letter from Mr. Elger, in which he says:—"Your letter of the 18th, relating to the markings on the floor of *Plato*, has greatly interested me, inasmuch as you therein suggest a theory to account for the remarkable appearances observed, which seems to me to be well worth careful consideration. Doubtless the sun's heat during the long lunar day *must* cause vaporization on the moon's surface, and subsequent condensation of the *various* vapours raised follows as a matter of course. So far we have a *vera causa* which would account for a great deal, *if we could only show that the vapours raised are sufficiently dense to produce* VISIBLE *effects*: it is highly probable that they are so, or, at all events, we may suppose that the varying visibility of such delicate objects as the spots on the floor of Plato is, to a certain extent, accounted for in this way; but I would submit that, in the case of the markings, it is difficult (if the dark spaces between the markings are the upper surfaces of masses of vapour hovering over the floor, and of course varying in altitude from hour to hour) to account for the fact, that since the year 1866 the light streaks have altered so little in *shape* and *position*. It seems to me that if they were merely openings in the dense vapour, they would not only vary in position from lunation to lunation, but changes would take place from hour to hour, which could hardly be overlooked by observers with powerful instruments: Linné is a case in point. The observation of June 1867 is in perfect harmony with your theory; indeed the phenomena presented by this remarkable formation are, I think, quite inexplicable, except by supposing agencies of the kind suggested by you to be in operation. At some future time, when selenography is more advanced, it will probably be found that all

objects on the *Maria* and *low-lying tracts* are more or less variable in visibility."

In reference to Mr. Elger's remarks, an important question may be suggested. Is the moon surrounded by an atmosphere of elastic gas? This question has been answered in the negative, inasmuch as in the phenomena of occultations no distortion or bending of the rays of light from the stars occulted has been noticed. If I remember rightly, this is the basis of the negation: Mr. (now Sir W. R.) Grove, in his address to the members of the British Association at Nottingham in 1866, alluded to the unsolved state of the question; and, "supposing the moon to be constituted of similar materials to the earth, it must be," he said, "doubtful if there is oxygen enough to oxidize the metals of which she is composed; * * * and it might be a fair subject of inquiry whether, if there be any coating of oxide, it may not be so thin as not to disguise the form of the congealed metallic masses, as they may have set in cooling from igneous fusion." The presence of oxygen, inferred from oxidation, presupposes an atmosphere of permanently elastic gas or gases. From the investigations of Herr Althaus, it has been approximately estimated that the moon's hemisphere turned towards the earth attains at least a maximum temperature of 840° of Fahrenheit, upon the assumption that the moon's power of absorbing heat is equal to that of quartz. The heat thus attained would very closely approximate to the temperature at which iron appears red in twilight, and exceeds the fusing-points of *tin* and *lead*. On the other hand, the minimum is estimated to be −92° of Fahrenheit, which would give a fall of about 940° in fifteen days; this would be equivalent to daily increments and decrements of heat of about 63° each. This enormous variation must be attended with very considerable expansion and contraction of the gases, either present or liberated, and a very rapid diminution of temperature upward must result. Now about the period of maximum temperature of the luni-solar day the surface, whatever materials may compose it, *must* be in a very different condition to what it existed in at sunrise; and this is so far *visible* to us by the different aspects of objects under high illumination, so graphically described by Webb, and also by the intensely glowing luminous spots, such as Aristarchus, Censorinus, Dionysius, and various streaks under a midday sun. If the heat exceeds the melting-points of tin and lead, it is quite possible that, long before the maximum temperature is attained, substances may be fused and vapours given off which, rising quickly to a cooler region, may be condensed and become visible to us as cloud.

As regards the streaks on Plato, it has been proved by observation that the floor is irregular, although it generally appears to be smooth and even: it is known in some places to rise slightly above a mean level and to sink in others slightly below; and this depressed character is most prominent at the interior foot of the surrounding mountain-ring. The principal craterlet is situated upon the highest part of the floor, and from it radiate the arms and stem of the "trident." It is not at all unlikely that the great heat to which the surface is subject may at times produce eruptions from this and other craterlets; indeed we appear to possess evidence that this has actually taken place at least twice within the period of the observations; and the arms, as well as the sector and great northern streak, may owe their existence to such eruptions, which of course would give them a permanent character. Subjected to the intense cold of the lunar night, at sunrise they would only reflect the same amount of light as the other portions of the floor; but as the floor becomes unequally heated, some portions absorbing heat while others

reflect more light, they would stand out as luminous streaks and markings, to be partially or wholly obscured by any condensed vapour which may happen to be floating above them. An absence of condensed vapour would impart to the floor a sharpness and definiteness so often observed, by the aid of which very minute objects are easily seen, while even a slight film, analogous to our cirrostratus cloud, would impart a mistiness by which the more delicate spots and streaks would be obscured, the broader features still remaining visible—a state of things of which evidence exists in the observations, and which has been observed more or less since the time of Hevelius, who relates that "several times he found, in skies perfectly clear, when even stars of the sixth and seventh magnitudes were visible, that at the same altitude of the moon, the same elongation from the earth, and with one and the same telescope the moon and its maculæ did not appear equally lucid, clear, and conspicuous at all times, but were much brighter and more distinct at some times than at others."

In a letter written under date of September 27, 1871, the Rev. T. W. Webb suggests that there is more inequality than we have yet studied in the reflective power of different substances at different angles of illumination or incident light. "It may be," he says, "that different colours behave differently when treated in this way; and I suspect they do: *e.g.*, if from the surfaces of certain materials the capacity for reflection of blue rays should increase more rapidly than that for red, then with increasing angle of illumination the colour of the object would slightly change, and with it its proportional visibility at a distance where colour becomes imperceptible. * * * Is it not possible that other circumscribed regions in the moon, *e. g.* that glorious Archimedes, might show variations in the markings even more definite and considerably more easily dealt with than those in Plato? The curiously but *occasionally* speckled and streaky aspect of the *Mare Crisium*, as described by Schröter, B. & M., and others, would be a grand case were it not so rare. If we could only find some smaller and more easily studied surface, equally or more frequently varied, it would be a great matter. But is there not something of a more general character underlying, as it were, these special instances that has never yet been properly investigated? We lay it down, as if it were unquestionable, that local colour in the moon is masked in the rising and setting illumination, and comes out under high angles when the shadows disappear. It may be so; but why? If I took a piece of plaster of Paris, moulded it into all sorts of hollows and knobs, and painted it harlequin fashion, then the colouring would be all equally visible, whether under oblique or vertical illumination; or, to make it more like the moon, if the artificial surface were only shaded with brownish or bluish greys we should have the same effect; as long as there was light enough to show it, the distinction of colour would remain. On the moon it is far less evident, and frequently quite imperceptible. Now what underlies this? Why do certain very dark spots on the moon come out under high illumination, or certain brilliant specks, being much less if at all contrasted with the neighbourhood when near the terminator? Could we produce an artificial surface which would behave in the same way? *Why* should this difference (whatever may be its cause) depend, not on the angle of incidence, but on that of reflection; for the full-moon aspect extends over the whole disk, notwithstanding the low illumination of the regions all round the limb, many of which show spots as vivid or as deep as more central regions? No one, so far as I know, has touched at all on this very interesting point."

Mr. Webb's suggestions and queries are very important. On that of an

irregular surface painted with different colours presenting an equally diversified appearance, whether the incident light were oblique or vertical, and the distinction of colour remaining so long as sufficient light existed to show it, I would remark that there can be no doubt that the moon's surface is as much variegated with colour as the earth's, but by distance the distinction of colour is softened down to tones of grey, in the same manner as we are able to distinguish nothing but greys in a distant terrestrial landscape. It is the telescope which brings out the distant red-brick building or the dazzling whiteness of the church steeple under a noonday sun, the predominant colour of the landscape being either the delicate green of spring, the deeper green verging on blackness in summer, or the rich reds, browns, or yellows of autumn. These are the colours which characterize the foliated covering of the earth, interspersed with a sandy or even white tint indicative of the existence of vast desert tracts. At the distance of the moon we only perceive on her surface various tints, from a dark blackish grey to a dazzling white; and these are certainly intensified under vertical illumination, but most decidedly under that reflecting angle the value of which is measured by the supplement of the difference of longitude of the moon and sun when it is equal to zero, or supplement ☾ − ☉ = 0°. Perhaps the following experiment may set this matter in a clearer light. Take an ordinary cream-coloured envelope and place within it a piece of bluish paper, so that the two tints may appear in juxtaposition, also a piece on which various shades of grey have been dabbed, as trials used in colouring. If these are held or placed in such a position that very oblique light may fall upon them from a lamp, although the distinction of colour may be perceptible, it will be, under the *earliest* illumination, so very slight as to be hardly cognizable if viewed from an angular position equal to the supplement of 90°: *i.e.* let the lines from the lamp to the illuminated surface just grazed by the incident rays and from the same surface to the eye form an angle of 90°; now let the lamp, eye, and illuminated surface be brought into the same plane, although not into the same line, and it will be found that the tints become much more distinct. No more light falls upon the surface than before; but the eye views the surface under a different disposition of the angles of incidence and reflection, the consequence being a better appreciation of its inherent light and shade. By placing the different shaded papers in such a position that the light from the lamp falls perpendicularly upon them, and bringing the eye as nearly as possible into the same perpendicular line, we view the paper as we view the full moon, the tints coming out in the strongest manner possible; and this is in accordance with the law that the greatest quantity of light is irregularly reflected with the smallest angle of incidence. As the diameter of the moon subtends a maximum angle of less than thirty-three minutes of arc, the rays coming or reflected from her are nearly parallel; from which it follows that the path of the solar rays impinging on the moon, and passing to the earth, will be nearly as the sides containing the angle known as the supplement of the moon's elongation from the sun, which at full equals 0°.

In applying our experiment to the moon in all its generality, we ought to have a regular increase and decrease of *intensity* of tint, subject to small but also to very regular variations. Is it so? In one remarkable and well-observed instance, at so early a period as twenty-four to thirty-six hours after sunrise on Plato, the north-west portion of the floor was so strongly illuminated as to obliterate the well-known north-west streak. This appeared to be an abnormal brightening of the floor, and must have been quite independent of illuminating or reflecting angle; its bearing upon Mr. Pratt's

remarks relative to an unusual exhalation of vapour causing an extension of lucid area (see *post*, p. 261) or a flowing together of neighbouring light-streaks is obvious. On the 12th of May, 1870 (the brightening of the floor was observed on the 9th of May), it had so far subsided as to allow of the north-west streak being seen, one observer (Mr. Gledhill) recording it as the brightest on the floor, another (Mr. Elger) registering the part east of spot No. 16 as very bright and well defined. This was from 96 to 108 hours after sunrise. That this increase of light was independent of either illumination or reflection, except as transmitting agents, is evident from the fact that at the same interval from sunrise, 96 to 108 hours on the 14th of March, 1870, the eastern arm of the "trident" was recorded as the brightest marking.

Mr. Pratt, writing under dates October 17 and 18, 1871, says:—"A year or two since I was reading Kirchhoff's 'Memoirs,' Roscoe's 'Spectrum Analysis,' and several other works on the subject, and at the same time frequently spent an evening in Mr. Mayall's laboratory with his splendid spectroscope. About that time I often considered the possibility of vapours rising from the heated surface of the moon, and wondered if the dark spaces were in any way absorptive clouds, and became of the opinion, and am so still, that both the darkest and the lightest markings on the surface may be but the appearances of vapours. . . . Looking at Proclus, Aristarchus, and the interior of Tycho, I can never feel certain that their brilliancy is merely the dazzling reflection from naked rocks; and that great valley running N.E. from Tycho suggests other causes for its whiteness than merely different incident and reflecting angles and different materials of its soil. The Mare Frigoris has very often suggested to me (and I have mentioned the same to you more than once) both the possibility and probability of its being covered with something very foggy in its nature. It has frequently had that appearance in my telescope; and while objects on the heights of the rim of Plato have been well defined, a general haziness has belonged to those on the Mare below,—full proof, I think, that the obscuration not only belonged to the moon itself, but was confined to its lower levels. That under the circumstances the intense heat must produce vapours from the surface, even if small in quantity, and that, once produced, they must act as your theory supposes, seems incontrovertible. Some visible effects of their production, both in absorption and reflection of solar rays, must follow as a natural consequence; and if those instances you have thought proper to adduce are not real observations of those visible effects, it remains for some more assiduous observers to bring forward more complete proof of their presence; but I cannot then see that even the supposed presence of such vapours is in the least degree negatived. The proof of their presence by observation of their effects would only be in abeyance. Does not the softened margins of light-streaks generally on the moon suggest a vaporous origin? Surely, in the case of Linné, it is as reasonable as that the white spot arises from reflection from a surface of shivered glass. The past observations of Linné and your present theory fit well together; and it seems to me that if one may be forgiven for supposing the presence of a small quantity of moisture on the moon, then the *hotter* the surface the *whiter* the spots and streaks would become to our view."

[In reference to Mr. Pratt's remark on the *whiteness* of the heated surface, I may call to mind the appearance of *slated* roofs under a July or August sun which I have noticed. It is just as if the slates had been coated with a *white* pigment. Instead of a dark slaty hue they have presented a strongly decided white, so as to induce the belief that the roof had been whitewashed or painted white. Having given some attention lately to the so-called *irregular*

reflection of light, in connexion with the above remark I may notice that an increase of light from dark slated roofs is observed as the sun approaches such a position in the heavens, with regard to the eye, ... [illegible] roofs consisted of polished surfaces an image of the sun would be seen at the moment when the angle of reflection equalled the angle of incidence; and this tendency to the formation of an image is greatly augmented by a falling shower, the rain bringing the slates more into the condition of a watery surface, rendering them comparatively darker, except at those points where the two angles meet. Irregular and roughened surfaces on the moon will consequently appear *brighter* at those periods in the lunation when the light from the sun to the moon, and thence to the eye, falls in the lines of incidence and reflection. At all times irregular reflection from the moon is independent of the incident rays; but an approach to regular reflection attended with increase of light, the epoch of which for each point of the moon's surface is clearly calculable, must occur during every lunation, so that all normal brightening may be easily detected.]

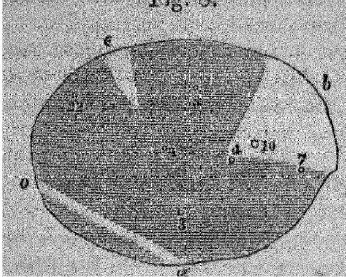
"Starting from the hypothesis, it seems to me that your explanation of the *variation of position of the light-streaks* must be held a very reasonable one; and I beg to add a small supplement. I suppose that the maxima of midday heat at the latitude of Plato are not always the same, that they run through a slight seasonal variation, then a periodical difference in the quantity of vapour raised would result; and if the general outline of the light-streaks is the result of the local conformation of the ground as related to the craterlets, then an unusual amount of vapour raised, might cause two or more light-streaks apparently to flow together for a time, producing an entire change in their outline, afterwards, as the heat lessened, to resume their most usual appearance. I have often thought the light-streaks suggested the remembrance of the mists and fogs which may be seen on an autumnal evening from the elevated parts of our downs; as evening advances the mists gradually appear winding about in streaky shapes or isolated in irregular patches, *according to the formation of the ground*, while their margins, sometimes sharp, are generally soft and ill-defined, very much like lunar light-streaks to my mind, if they could be seen from a nearly perpendicular direction.

"There is a difficulty as to the nature of the dark tints, supposing them to be cloudy coverings; but is it quite certain that the *middle tint* is really the true colour of the soil? What if the *darkest tint* was the colour of the naked surface, and if the *middle tint*, which appears at sunrise and sunset, is a *covering* of the nature of hoar frost, the vapour which is supposed to be raised during the luni-solar day freezing again on the sudden approach of night? But we are supposing the presence of moisture on the moon. We must not forget the Baconian maxim."

[Mr. Pratt's idea of *hoar frost* is very suggestive; not that the appearance of the surface near the terminator is of that nature in the sense in which we employ the term, for one would think that then the reflected light would be most certainly *white*; yet it cannot be denied that, generally speaking, within about 10° of the terminator, the surface of the moon is such as we may suppose that of the earth to present after a cold clear frosty night, the atmosphere being exceedingly translucent, so that objects are readily and clearly visible. The lunar night must be intensely cold, with enormous radiation, by which, whatever gas or vapour may exist, both its bulk and elasticity would be greatly reduced, especially towards sunrise; so that it is quite possible that an atmosphere, if such there be, would be of the rarest character, and this would fully account for the clearness and sharpness of objects at

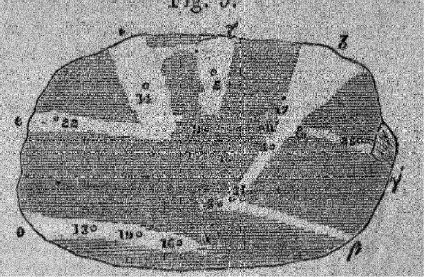
divide it into two separate streaks, that east of spot No. 16 being designated "*a*," the western part "*o*." On October 19 Mr. Gledhill delineated it as a narrow streak (see fig. 17, p. 288); but as he omitted the western part of the

Fig. 8.



Plato, 1869, Sept. 20.—T. G. E. Elger.

Fig. 9.



Plato, 1869, Sept. 25.—J. Gledhill.

floor it is uncertain if the continuation reached the border. On the 21st it was recorded as brighter than on the 19th. On the 25th a dark space was seen between it and the border; and it was observed by Mr. Gledhill on the 26th and on the 27th, in the interval between 12 hours and sunset.

Lunation November 1869, *from* 117 *hours before to* 21 *hours after meridian.*

On November 14, at an earlier epoch than it had hitherto been observed, Mr. Gledhill recorded the streak as seen east of spot No. 16, the western part "*o*" being absent. On January 12 Mr. Elger (same interval, 60 to 72 hours) showed in his drawing the continuation "*o*," with an extension of its north-west border to the north-west border of Plato, *i. e.* the floor from the south-east border of "*o*" to the rim of the crater was equally bright; this brightness commenced on the east at Webb's elbow. On the 19th of November the continuation "*o*" was observed contemporaneously with *c*, which reached nearly to *δ*, and was *convex* towards the border. This is in contrast with later observations, in which *c* was seen *concave* towards the border (see lunation April 1870, *post*, p. 264). The contemporaneity of *c* and "*o*" indicates that a change had supervened between the first observation in September and November 19, on which day Mr. Gledhill recorded *a* as the *brightest* streak on the floor, and first observed Webb's elbow.

Lunation December 1869, *from interval* 24 *to* 36 *hours after sunrise to interval* 48 *to* 36 *hours before sunset.*

This lunation afforded as many as ten observations of Plato, so that the progression of the illumination of the streak could be well traced. At first, on the 12th, it was seen with difficulty, the north-west part of the floor being brightest. On the 13th it was still difficult to separate from the north and north-west part of the floor; but on the 14th it was seen continued in "*o*," the two forming the *brightest* and best-defined streak on the floor. Interval 72 to 84 hours. The observations of December 12 and 13 are the earliest of the bright north-west floor, which would, from its dip towards the border, reflect more light soon after sunrise than at a later period of the luni-solar day; and it may have been from this circumstance that the brightness of the streak merged into that of the floor. It is, however, noteworthy that on February 9, 1870, interval 24 to 36 hours after sunrise, the streak *a* should

have been seen as a sharp narrow bright streak, from the tip of the most northern shadow to the north-east border nearly parallel with a line through spots Nos. 1 and 4, and no mention of a bright floor in its neighbourhood.

On December 15, interval 96 to 108 hours after sunrise, the continuation "*o*" was seen "fairly bright," but on the 17th it was not recorded; a new phase, however, was noticed, viz. Webb's elbow, which was continued in *c*, terminating the streak recorded as very bright on the west. This phase was more fully developed on April 14, 1870. The brightness of the streak continued from December 17 to December 24; indeed it was recorded as the *brightest* on December 21, 22, and 24.

Lunation January 1870, from 36 hours after sunrise to 33 hours before meridian passage.

On January 11, 1870, 36 to 48 hours after sunrise, the streak was well seen, its brightness blending with the bright north-west floor. On the 12th, 14th, and 15th, the continuation "*o*" was observed. On the 15th, 132 to 144 hours after sunrise, the streak *a*, which extended from Webb's elbow, was quite separated from the border.

Lunation February 1870, from 24 hours after sunrise to 69 hours before meridian passage.

On February 9, interval 24 to 36 hours after sunrise, as remarked under the December lunation, the streak was recorded as "sharp, narrow, and bright." Either the streak must have been brighter than in December, as seen during the same interval, or the floor darker; whichever of the two was the real state, the difference is not explicable on a change of illuminating angle, the altitude of the sun being the same both in December and February. On February 11 and 12 the streak was well seen, being recorded as very broad and bright on the 12th.

Lunation March 1870, from meridian passage to 24 hours before sunset.

The observations during this lunation were made under the reverse light, *i. e.* after meridian passage. On the 17th and 19th of March the streak *a* and the sector were the brightest markings on the floor. On the 23rd, under a declining sun, the streak appeared diffuse and extending up to the north border. This is remarkable, and indicative of the brightness not being due to illuminating angle, which, from the slope towards the north-west border being turned from the sun, would render the floor *darker* as seen by Mr. Pratt on August 28, 1869, and by Mr. Gledhill on March 24 and November 15, 1870. (See Report Brit. Assoc. 1871, pp. 86, 87.)

Lunation April 1870, from 36 hours after sunrise to 45 hours after meridian passage.

The principal feature in the earlier observations of this lunation is the indefiniteness of the continuation "*o*" which appears in Mr. Elger's sketch of April 10 (see fig. 12, *post*, p. 275), but was not seen by Mr. Gledhill as a distinct sharp streak on that day. On the 11th it was very hazy and ill-defined. On April 14, interval 132 to 144 hours, the floor presented quite a different aspect (see fig. 15, *post*, p. 285) to that of April 10, the continuation "*o*" being entirely absent, and the elongation of streak *c* towards the western arm of the trident *e* being concave towards the western border. On the last occasion, November 19, interval 168 to 156 hours, when *c* extended

towards the south-west, the concavity was in the opposite direction (see Lunation November 1869, *ante*, p. 263). The streak *a* extended on the 14th of April from Webb's elbow, and was quite separated from the northern border of Plato. On the 15th it was recorded as very bright, the projecting portion of *c* being brighter than on the 14th, and nearly joining the western arm of the trident; the continuation "*o*" was not seen. On the 16th *c* had disappeared, *a* being recorded as bright and sharp. On the 17th it was recorded by Mr. Gledhill.

In this lunation "*o*" was seen from 36 to 84 hours after sunrise. The observations of April 11, 1870, and December 14, 1869, are synchronous as regards interval from sunrise. On December 14 *a* and "*o*" formed together the *brightest* and best-defined streak on the floor. On April 11 "*o*" was very hazy and ill-defined. These opposite characters under the same solar altitudes, as well as those recorded in the previous February lunation, cannot be explained on the hypothesis of changes of illuminating angle, for there were none, but point to some agency operating within the enclosure of Plato. The appearance of the portion of *c* projecting towards the western arm of the trident on the 14th, its nearly joining the arm on the 15th, and its disappearance on the 16th, combined with the opposite directions of the convexity in November and April, again point to recent or, we may say, present local action.

Lunation May 1870, from 24 hours after sunrise to 33 hours before meridian passage.

The commencement of the observations during this lunation was characterized by the north portion of the floor being brighter than hitherto observed. On May 9 both Mr. Gledhill and Mr. Elger recorded independently this increased brightness; in consequence the streak *a* could not be traced. The moon's latitude at midnight was 4° 21′·9 N., Plato at that time being north of its mean position. On May 10 the streak *a* was seen by Mr. Gledhill. On May 12, interval 108 to 120 hours, or from 12 to 24 hours before the apparition of the projection *c* in April, this marking, although plainly seen, could not be traced so far to the south as in April, nor was it so sharply defined as in that lunation; indeed all the west portion of the north-west area was hazy as on April 11 and 12, and also on June 10. While this haziness characterized the western part of the floor, the area east of spot No. 16 was free from it; the streak *a*, as seen by Mr. Elger, was very bright and well defined. Is not this indicative of the haziness being due to local lunar action, and of the restriction of such action to a very small area of the surface, also of the inefficiency of change in the illuminating angle to explain it? On May 13 the streak *a* was recorded as bright and well defined, and very bright at the locality of spot No. 19.

Lunation June 1870, from 105 to 69 hours before meridian passage.

Two observations only were obtained during this lunation; the first on June 9, 72 to 84 hours after sunrise, when streak *a* (query its continuation "*o*") had the same nebulous appearance which it exhibited on May 10; the second on June 10, 96 to 108 hours after sunrise, when the eastern portion *a* was bright and well defined, the western portion "*o*" hazy, partaking of the general haziness of the north-west portion of the floor. These observations are in striking contrast with those of February (see *ante*, p. 264), in which neither the haziness nor the continuation "*o*" were observed. The

brightness on the north-west portion of the floor appears to have declined since May 9.

Lunation July 1870, *from* 117 *hours before to* 81 *hours after meridian passage.*

Three observations were obtained in this lunation,—on July 8, 60 to 72 hours after sunrise, when streak *a* was seen as a bright object; on July 14 and 16, from 156 to 96 hours before sunset, a condensed brightness in the central part of streak *a* being witnessed.

Lunation August 1870, *from* 9 *hours before to* 141 *hours after meridian passage.*

Three observations are the only ones recorded, the first on August 11 near meridian. In a drawing by Mr. Elger streak *a* is shown as very narrow, and quite separated from the north border, the west end crossed by the projection *c* from Webb's elbow; "*o*" was not seen. On the 13th the streak was seen by Mr. Gledhill, a dark tint of floor being recorded by Mr. Pratt. On the 17th the streak was recorded by Mr. Gledhill as the brightest amongst the faint streaks observed.

Lunation October 1870, *from* 81 *hours before to meridian passage.*

Two observations only were obtained,—the first on October 6, interval 96 to 108 hours, when streak *c* was seen quite detached from the border, and figured as narrow by Mr. Elger; the second on October 9, seen near meridian, when it (*a*) was shown as narrow by Mr. Elger, quite separated from the north border, the west end crossed by Webb's elbow and *c*; these together form a curved streak, concave towards the west border (see *ante*, pp. 263–265), the continuation "*o*" being entirely absent.

Lunation January 1871, *from* 168 *to* 132 *hours before sunset.*

In the first of two observations in this lunation, made on January 7, the north-west part of the floor is recorded as being in the same state as in August 1869 (see *post*, p. 269); in the second, on January 8, Mr. Gledhill recorded the streak *a* as sharply defined, bright, narrow, and straight.

Lunation March 1871, *from interval* 72 *to* 84 *hours to interval* 96 *to* 108 *hours after sunrise.*

On the second interval, 72 to 84 hours, the streak *a* was seen extending from spot No. 19 to spots Nos. 20 and 21; it is described as having been very distinct. On the third interval, 96 to 108 hours, it was observed by Mr. Pratt as the fourth in order of brightness, the sector κ and β being brighter.

Erratum.—Fig. 9, p. 263, *dele* connexion between streaks ζ and ϵ; not in original.

In the Report Brit. Assoc. 1871, p. 66, the position of streak *a* is given as determined by three sets of measures by Mr. Gledhill of the two ends of the streak on September 13 and December 9, 1870, and May 1, 1871. The streak is shown in fig. 4 of that Report as long and narrow. The numerous observations of the floor, including those of streak *a*, show that not only is the north-west part of the floor variable as regards its tint (light or dark), but that the positions of the streaks are also variable; and this variation is confirmed by the measures, which differ in value just as the recorded posi-

tions differ among themselves. The point of intersection of the measured streaks is in or near the locality of spot No. 19, at which a brightness has been observed. If the bright streaks are due to ejecta (see *ante*, p. 249), their varying positions may not be difficult of explanation.

On September 13, 1870, the measures which determined the position of streak α were as follows:—

For W. end on border parallel to	longest	diameter	$15''\!\cdot\!3$ =	·319.
„ W. „ „	transverse	„	10·2 =	·213.
„ E. „ „	longest	„	5·9 =	·123.
„ E. „ „	transverse	„	13·1 =	·273.

On December 9 they were as follows:—

For W. end on border parallel to	longest	diameter	16·1 =	·371.
„ W. „ „	transverse	„	4·5 =	·104.
„ E. „ „	longest	„	2·2 =	·051.
„ E. „ „	transverse	„	14·7 =	·339.

These measures are more in accordance with two separate streaks, or there may have been *four* streams of ejecta.

As illustrative of the probable permanency of the streaks, at least for some time, I quote the following from observations not included in the period embraced by the discussion:—

1871, October 22; interval 12 to 24 hours (?).—Mr. Elger noticed the north-west portion of the floor as equally light; and on November 27 he recorded the sector, Pratt's streak p and γ, as unusually easy; a diagram is given of α, Webb's elbow, and a portion of c, agreeing with fig. 14, p. 284.

1871, December 22, and following days.—Mr. Pratt noticed the haziness over the north-west portion of the floor so frequently observed in April, May, and June 1870.

In the following pages the observations of streak α are arranged, first chronologically, and second in the order of intervals from sunrise to sunset. It is presumed that these arrangements, combined with the foregoing remarks, will contribute to give a completeness to the history of a single feature closely observed during the greater portion of a period of two years.

History of Streak α, chronologically arranged.

Period of the recorded appearance of α, 1869, *Sept.* 20, *to* 1871, *March* 3.

The entire absence of this streak from the floor of Plato during the period of Mr. Pratt's observations in August 1869 *is noteworthy.*

1869.	h		h	
Sept. 20,	168	to	mer.	The first record by Mr. Elger's drawing with the continuation "o."
„ 25,	72	„	60.	Observations by Mr. Gledhill of the curvilinear streak from spot No. 13 to the sector, also of "o."
„ 27,	24	„	12.	α not seen, c described as a broad band of brightness. Width $\frac{1}{3}$ from spot No. 1 to rim.
Oct. 17,	108	„	120.	Well seen; covers spots 13, 19, and 16; alignment, if produced, would cut N. border of B. & M.'s A. West "o."
„ 19,	156	„	168.	Shown by Mr. Gledhill as a long narrow streak. Mr. Pratt mentions a portion of the floor near the mountain "m" on the north of the streak as very dark.
„ 21,	156	„	144.	Brighter than on the 19th.
„ 25,	60	„	48.	Dark space between the streak and border.
„ 26,	36	„	24.	Seen by Gledhill.
„ 27,	12	„	0.	Seen by Gledhill.

1869.	h h	
Nov. 14,	60 to 72.	Seen by Gledhill east of spot No. 16; "*o*" absent.
„ 19,	168 „ 156.	Continued in streak "*o*," with *c* reaching nearly to δ, convex to border. Contrast this with later observations, in which it was seen concave to the border; a change is manifest by the contemporaneity of *c* and "*o*." (See remarks under Sept. 25, p. 295.)

Brightness of N.W. area.

Dec. 12,	24 „ 36.	Seen with difficulty; N.W. part of floor brightest.
„ 13,	48 „ 60.	Difficult to separate from the bright N. and N.W. part of floor.
„ 14,	72 „ 84.	Continued in "*o*," the two forming the brightest and best-defined streak on the floor. The brightness of the N.W. area appears to have subsided.
„ 15,	96 „ 108.	Continued in "*o*;" fairly bright.
„ 17,	144 „ 156.	Very bright, extending from Webb's elbow, which is continued in *c*. This phase was more fully developed on April 14, 1870: Mr. Elger's observation.
„ 19,	168 „ 156.	Recorded as bright.
„ 20,	144 „ 132.	Recorded as bright, and extending from Webb's elbow.
„ 21,	120 „ 108.	The continuation "*o*" appears to have been lost after the 15th. Recorded as the brightest.
„ 22,	96 „ 84.	Recorded as the brightest.
„ 24,	48 „ 36.	Brighter than any other streak.
1870.		
Jan. 11,	36 „ 48.	Well seen; its brightness blends with bright N.W. floor.
„ 12,	60 „ 72.	Continued in "*o*."
„ 14,	108 „ 120.	Continued in "*o*."
„ 15,	132 „ 144.	Continued in "*o*," and extending from Webb's elbow; quite separated from border. Bright.
Feb. 9,	24 „ 36.	Seen as a sharp narrow bright streak from the tip of the most northern shadow to the N.E. border, nearly parallel with a line through spots 1 and 4. From Mr. Gledhill's measures combined the streak forms an acute angle with the longest diameter through spots Nos. 1 and 4 (see *ante*, p. 267).
„ 11,	72 „ 84.	Well seen by Mr. Gledhill.
„ 12,	96 „ 108.	Very broad and bright. The continuation "*o*" was not observed in February or March; in January it was seen from 60 to 144 hours after sunrise, also in Sept., Oct., Nov., and December.
Mar. 17,	mer. „ 168.	Recorded with sector by Mr. Gledhill as the *brightest* on the floor and easy.
„ 19,	132 „ 120.	Very bright, with the sector the *brightest* on the floor.
„ 23,	36 „ 24.	Diffuse and extending up to the N. border; easily but not well seen.
April 10,	36 „ 48.	Continued in "*o*;" ill-defined, especially at the N.W. Not seen by Mr. Gledhill as a distinct sharp streak. See Elger's drawing of this date (p. 275.).
„ 11,	72 „ 84.	"*o*" very hazy and ill-defined.
„ 14,	132 „ 144.	Extending from Webb's elbow, quite separated from the border, the streak *c* projected towards the south. See diagram by Mr. Elger (p. 285), in which the N.W. part of the floor presents a different aspect to that which it did on the 10th, four days earlier, "*o*" being entirely absent, and *c* with *e* exhibiting a concavity towards the border.
„ 15,	168 „ mer.	Very bright, projecting portion of *c* brighter than on the 14th, and nearly joining the western arm of the trident; the continuation "*o*" not seen.

1870. h h

April 16, 163 to 153. Bright and sharp; projection *c* has disappeared.

„ 17, 144 „ 132. Recorded by Gledhill; query "*o*."

In this April lunation "*o*" was seen from 36 to 84 hours, after which *c* was seen nearly joining *e* until meridian, after which it disappeared.

May 9, 24 „ 36. Could not be traced, northern part of floor equally bright as seen by Messrs. Elger and Gledhill. Moon's latitude 4° 21′·9 N.

„ 10, 48 „ 60. Seen by Mr. Gledhill.

„ 12, 108 „ 120. East of No. 16 very bright and well defined, as seen by Mr. Elger. It was seen by Mr. Gledhill east of No. 16, "*o*" being absent on Nov. 14, 1869, interval 60 to 72 hours. On May 12 the projection *c*, although plainly seen, could not be traced so far to the south as in April, nor was it so sharply defined as in that lunation; indeed all the west portion of the N.W. area was hazy as on April 11 and 12, and also on June 10.

This haziness on the N.W. part of the floor while E. of spot No. 16 was well defined is very noteworthy, as indicative of the haziness being due to local lunar action, and restricts such action to a very small area of the surface.

„ 13, 132 „ 144. Bright and well defined; very bright at the locality of spot No. 19.

June 9, 72 „ 84. The streak *α* (query its continuation "*o*") had the same nebulous appearance which it exhibited on May 10. The brightness on the N.W. part of the floor appears to have declined since the early part of the May lunation.

„ 10, 96 „ 108. The east portion (*a*) bright and well defined, the west portion hazy; it appeared to partake of the general haziness of the N.W. quarter of the floor.

These observations are in striking contrast with those of February, in which neither the haziness nor the continuation "*o*" were observed.

July 8, 60 „ 72. Seen as a bright object.

„ 14, 156 „ 144. Condensed brightness in the middle.

„ 16, 108 „ 96. Condensed central portion.

Aug. 11, 168 „ mer. Shown as very narrow by Mr. Elger, and quite separated from the north border, the west end crossed by *c* and *i*; no "*o*."

„ 13, 144 „ 132. Seen by Mr. Gledhill; dark tint of floor recorded by Pratt.

„ 17, 48 „ 36. Recorded by Gledhill as the *brightest* amongst the faint streaks observed.

Oct. 6, 96 „ 108. Quite detached from the border, and figured as narrow by Mr. Elger; no "*o*."

„ 9, 168 „ mer. Shown as narrow by Mr. Elger, and quite separated from the north border; the west end crossed by *i* and *c*, which together form a curved streak concave towards the west border, the continuation "*o*" being entirely absent.

1871.

Jan. 7, 168 „ 156. No mention of *a*; the N.W. part of the floor in the same state as in August 1869. (See figs. 4 & 5, p. 252, and figs. 6 & 7, p. 254.)

„ 8, 144 „ 132. Recorded by Gledhill as sharply defined, bright, narrow, and straight.

Mar. 2, 72 „ 84. Extending from spots No. 19 to Nos. 20 and 21; very distinct.

„ 3, 96 „ 108. The fourth streak in order of brightness as observed by Mr. Pratt, the sector *κ* and *β* being *brighter*.

Arrangement in order of Intervals.

h h		
24 to 36,	1869, Dec. 12.	Seen with difficulty, N.W. part of floor brightest.
	1870, Feb. 9.	Seen as a sharp, narrow, bright streak from the tip of the most northern shadow to the N.E. border, nearly parallel with a line through spots Nos. 1 and 4.
	„ May 9.	Could not be traced; the northern part of the floor equally bright as seen by Messrs. Elger and Gledhill. Moon's latitude at midnight 4° 21′·9 N.
36 „ 48,	1870, Jan. 11.	Well seen, its brightness blending with the bright N.W. floor.
	„ April 10.	Continued in "*o*;" ill-defined, especially at the N.W. Not seen by Mr. Gledhill as a distinct sharp streak. See Mr. Elger's drawing of this date, fig. 12, p. 275.
48 „ 60,	1869, Dec. 13.	Difficult to separate from the bright N. and N.W. part of floor.
	1870, May 10.	Seen by Mr. Gledhill.
60 „ 72,	1869, Nov. 14.	Seen by Mr. Gledhill east of spot No. 16; "*o*" absent.
	1870, Jan. 12.	Continued in "*o*."
	„ July 8.	Seen as a bright object by Mr. Gledhill.
72 „ 84,	1869, Dec. 14.	Continued in "*o*," the two forming the *brightest* and best-defined streak on the floor.
	„ Feb. 11.	Well seen by Mr. Gledhill.
	„ April 11.	"*o*" very hazy and ill-defined.
	„ June 9.	The streak *a* (query its continuation "*o*") had the same nebulosity which it exhibited on May 10.
	1871, Mar. 2.	Very distinct, extending from spot No. 19 to Nos. 20 and 21; "*o*" absent.
84 „ 96	....	No observation.
96 „ 108,	1869, Dec. 15.	Continued in "*o*," fairly bright.
	1870, Feb. 12.	Very broad and bright.
	„ June 10.	The east portion *a* bright and well defined, the west portion "*o*" hazy; it appeared to partake of the general haziness of the N.W. quarter of the floor. (See note in chronological arrangement.)
	„ Oct. 6.	Quite detached from the border, and figured as narrow by Mr. Elger; "*o*" absent.
	1871, Mar. 3.	The fourth streak in order of brightness as observed by Mr. Pratt, the sector κ and β being brighter.
108 „ 120,	1869, Oct. 17.	Well seen by Mr. Gledhill; it covers spots Nos. 18, 19, and 16; alignment, if produced, would cut N. border of B. & M.'s A.
	1870, Jan. 14.	Continued in "*o*."
	„ May 12.	East of spot No. 16 very bright and well defined as seen by Mr. Elger; the projection *c*, although plainly seen, could not be traced so far to the south as before, nor was it so sharply defined as before; indeed all the west portion of the N.W. area was hazy, as in April and June.
120 „ 132	....	No observation.
132 „ 144,	1870, Jan. 15.	Continued in "*o*," and extending from Webb's elbow; quite separated from the border.
	„ April 14.	Extending from Webb's elbow, and quite separated from the border, the streak *c* projecting towards the south. (See note in chronological arrangement.)
	„ May 13.	Bright and well defined; very bright at the locality of spot No. 19.
144 „ 156,	1869, Dec. 17.	Very bright, extending from Webb's elbow, which is continued in *c*.

h h

156 to 168, 1869, Oct. 19. Shown by Mr. Gledhill as a long narrow streak; Mr. Pratt mentions a portion of the floor near the mountain "*m*" on the north of the streak as very dark.

168 „ mer., „ Sept. 20. Continued in "*o*." (See fig. 8, p. 263.)

1870, April 15. Very bright, the projecting portion of *c* brighter than on the 14th (interval 132 to 144 hours), and nearly joining the western arm of the trident; the continuation "*o*" not seen.

„ Aug. 11. Shown as very narrow by Mr. Elger (see fig. 18, p. 289), and quite separated from the border, the west end crossed by *c* and *i*; no "*o*."

„ Oct. 9. Shown as narrow by Mr. Elger (see fig. 19, p. 289), and quite separated from the north border, the west end crossed by *i* and *c*, which together form a curved streak concave towards the west border, the continuation "*o*" being entirely absent.

These observations (interval 168 hours to meridian passage) are quite sufficient to show that the change that supervened between the 20th of September, 1869, and the 15th of April, 1870, is independent of illuminating angle and its variations, the new disposition seen in April of the streaks on the N.W. part of the floor continuing to October 9, 1870, at this period of the luni-solar day.

mer. „ 168, „ Mar. 17. Recorded by Mr. Gledhill as easy, and with the sector as the *brightest* on the floor.

168 „ 156, 1869, Nov. 19. Continued in streak "*o*," with *c* reaching nearly to *δ*; convex to west border. This is greatly in contrast with the observations of October 9, 1870 (see interval 168 hours to meridian).

„ Dec. 19. Recorded as bright.

1870, April 16. Bright and sharp; projection *c* has disappeared.

1871, Jan. 7. No mention of *a*; the N.W. part of the floor in the same state as in August 1869 (see figs. 5, 6, and 7).

156 „ 144, 1869, Oct. 21. Brighter than on the 19th of October, 1869 (see interval 156 to 168 hours).

1870, July 14. Condensed brightness in the middle.

144 „ 132, 1869, Dec. 20. Recorded as bright, and extending from Webb's elbow.

1870, April 17. Recorded by Gledhill; query "*o*." (See note in the chronological arrangement.)

„ Aug. 13. Seen by Gledhill; a dark tint of floor recorded by Pratt.

1871, Jan. 8. Recorded by Gledhill as sharply defined, bright, narrow, and straight.

132 „ 120, 1870, Mar. 19. Very bright, with the sector the *brightest* on the floor.

120 „ 108, 1869, Dec. 21. Recorded as the *brightest*.

108 „ 96, 1870, July 16. Condensed central portion.

96 „ 84, 1869, Dec. 22. Recorded as *brightest*.

84 „ 72 .... No observation.

72 „ 60, 1869, Sept. 25. Mr. Gledhill observed "*o*," also the curvilinear streak from spot No. 13 to the sector.

60 „ 48, „ Oct. 25. Dark space between the streak and border.

48 „ 36, „ Dec. 24. *Brighter* than any other streak.

1870, Aug. 17. Recorded by Gledhill as the brightest amongst the faint streaks observed.

36 „ 24, 1869, Oct. 26. Seen by Gledhill.

1870, Mar. 23. Diffuse and extending up to the north border, easily but not well seen.

24 „ 12, 1869, Sept. 27. *a* not seen, *c* described as a broad band of brightness, width about one third the distance from spot No. 1 to the border.

12 „ 0, „ Oct. 27. Seen by Mr. Gledhill.

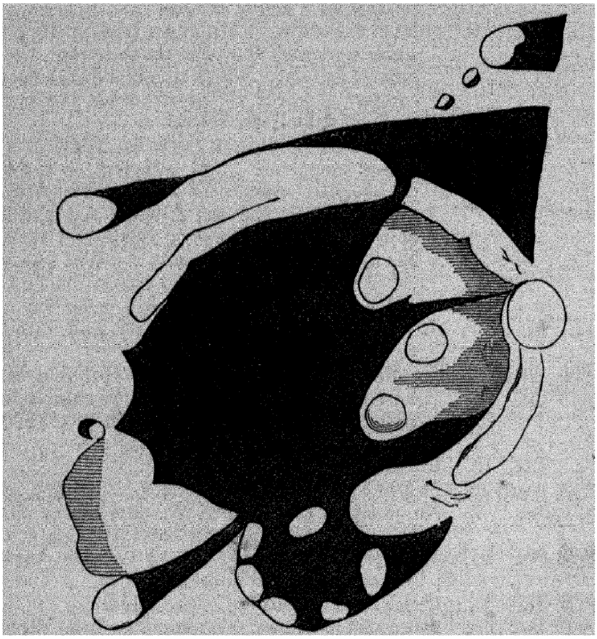
IV.

Observers' Notes.

Interval 12 to 24 hours.

State of floor at sunrise (fig. 10).—For observations at sunrise, see Report 1871, pp. 67 to 76, also p. 96, where the reader will find Mr. Pratt's observations

Fig. 10.



State of floor at sunrise, 1870, Nov. 1, 6^h to $6^h\ 40^m$.

of sunrise. In reference to the dip of the floor to the margin there mentioned, which is well established, I may remark that on the 20th of November, 1871, I noticed the streaks of sunlight at sunrise terminated on the east at some distance from the border, indicating a considerable dip of the floor, if the sunlight were reflected from the true floor. (See Report 1871, p. 68, Jan. 10, 3 hours.) In reference to the streak between spots Nos. 4 and 3, I would observe that the continuous observations of the streaks η and β by Messrs. Gledhill and Elger strongly indicate that they are connected with spots Nos. 4 and 3; the narrow shading between these spots, as shown by Mr. Pratt, is most likely a shallow depression between the streaks if Mr. Pratt's suggestion of their being spurs be correct (?).—W. R. B. Fig. 10 shows the dip of the floor to the E. border. Tint of floor 0·33.

The difficulty experienced on the night of Nov. 20, 1871, in obtaining a good view of sunrise on Plato (if inexplicable on the fact of different apertures having been employed, $7\frac{1}{3}$ in. on the 10th of Jan. 1870, and $2\frac{3}{4}$ on Nov. 20, 1871) may have been produced by an absorptive medium within the enclosure of Plato: the appearance mentioned in Report 1871, p. 68, was more intensified than I had previously witnessed, and the western portion of Plato, that

nearest the western border, was darker than the eastern; and there, where the sun's rays were more obstructed than further east, the peculiar appearance of something reflecting the stronger light from the brighter border above the surface was not seen. The most expressive description that I can give, after twenty-four hours' consideration, is, in the words of Schröter, "a kind of fermentation." It is certainly very unusual for the clearness of objects near the terminator to be interfered with; but should there have been "vapours" in motion, catching momentarily the reflected rays and, as the sun rose higher, the direct rays over the mountain-border, such an appearance as I witnessed must have been produced; and the presence of such vapours may occasion the darker tint of the floor, and especially the indistinctness of the boundary of the streaks of sunlight and the edges of the shadows. I never before observed the floor of Plato to be so dark; but I have seen it once only under similar circumstances, except that of aperture.

Interval 24 to 36 hours.

1870, May 9.—Mr. Elger's record is as follows:—"Markings not well seen" (but he does not specify them); "the sector was the brightest." He also says, "the northern portion of the floor [that which on August 26, 1869, was dark and extended between the streak *c* and the border] was noted as equally light; the streak *a* could not be traced." On the same evening Mr. Gledhill recorded the floor as light, $=0\cdot33$, and that streak *a* was not to be distinguished from the bright floor all along the north border. He described the streaks as faint and rather diffuse, the sector faint, not sharp at edges, and seemed broader than usual. Libration in latitude S. in August and N. in May would tend to throw streak *a* apparently nearer the N. border in May; but Mr. Gledhill could not distinguish it from the general brightness.

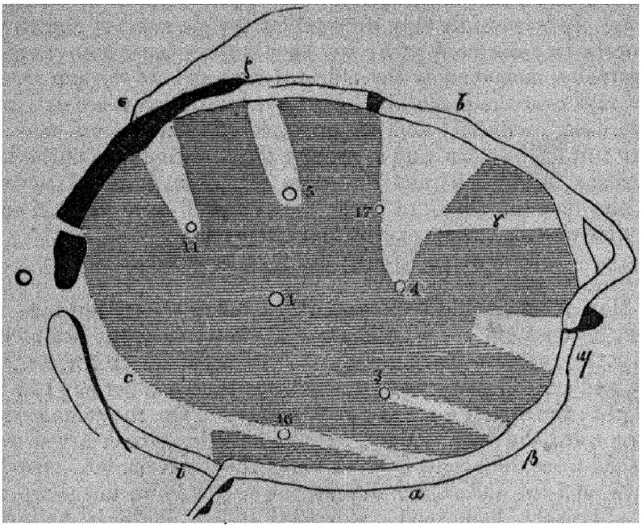
Chronological progression of increase of brightness on the N.W. part of the floor of Plato.

On referring to Mr. Elger's drawings of January 12, 1870, interval 60 to 72 hours, and January 14, 1870, interval 108 to 120 hours, I find the N.W. part of the floor extending from Webb's elbow to very nearly the position of the west arm of the trident equally light; indeed presenting on the 12th a similar contour to Mr. Elger's sketch of May 10, 1870, interval 60 to 72 hours, the difference being that on the 12th of January, 1870, the streak *a* was distinctly separated from the border. The streak *a* was first recorded by Mr. Elger on September 20, 1869, interval 168 hours to meridian passage, and his diagram of that date is strikingly in contrast with those of Jan. 12 and 14, and May 9 and 10 (see fig. 8, p. 263, and fig. 11, p. 274).

On September 25, 1869, interval 72 to 60 hours, we have a diagram (see fig. 9, *ante*, p. 263) of Mr. Gledhill's in which the N.W. part of the floor is figured as nearly similar to Mr. Elger's of the 20th, the streak including the three spots Nos. 13, 19, and 16. On October 17, 1869, interval 108 to 120 hours, Mr. Gledhill again saw the streak, and described it as a "well seen streak which covers 13, 19, and 16;" he aligned it thus: "the streak produced E.N.E. would cut the north border of B. & M.'s crater A outside Plato." On October 25, 1869, interval 60 to 48 hours, Mr. Gledhill gives a diagram in which *a* and "*o*" occur with a dark space between the streak and the border. On November 19, 1869, interval 168 to 156 hours, Mr. Gledhill saw the streak *a* with its continuation "*o*," Webb's elbow, and the streak *c*, "*o*" and *c* diverging from the western side of Webb's elbow. The earliest instance of an increase of light on the N.W. part of the floor, and of the observation of Webb's elbow during

the present series of observations, occurred on Nov. 15, 1869, interval 84 to 96 hours. See also December 13, 1869, interval 48 to 60 hours, p. 278, when

Fig. 11.



Plato, January 12, 1870.—T. G. E. Elger.

Mr. Gledhill recorded the N. and N.W. parts of the floor as brightest. On December 14, 1869, interval 72 to 84 hours, Mr. Elger sketched *a* and "*o*," with Webb's elbow, the west side of which merged into the streak "*o*." The streak *c* seen by Mr. Gledhill and the spots Nos. 13, 19, and 16 were not seen. Mr. Gledhill mentioned the bright floor connecting *a* and δ without a distinct streak. The next day, Dec. 15, interval 96 to 108 hours, the elbow is not separately given; the two sketches (see figs. 11 and 13) very much resemble those of January 12 and 14, 1870. The state of the N.W. part of the floor was nearly similar during the two lunations, the greatest amount of light being observable at the earlier epoch in both cases. Mr. Gledhill noticed the N.W. part of the floor bright on January 11, interval 36 to 48 hours. In Mr. Elger's diagram of Sept. 20, 1869 (*ante*, p. 263), he gives three light markings—the sector *b*, the middle arm of the trident ϵ, and a straight marking on the N.W., replacing the curved streak *c* of Pratt of August 1869. The western branch of this streak appears to be connected with spot No. 19. To distinguish it from *h*, which crosses it, it is designated "*o*;" the eastern portion which joins the N. border is *a*. On December 20, 1869, interval 144 to 132 hours, the floor was approaching its normal state.

1870, March 11.—Mr. Gledhill recorded the floor as "medium, =0·50, like the tint of the Mare Frigoris."

1870, February 9, 4.45.—Mr. Gledhill described the floor east of a line through spots Nos. 1 and 3, produced both ways, as "dusky." At 7 hours Mr. Gledhill writes, "E. part of floor still dusky as far as the east edge of sector, and a line along this edge produced to the north border."

Streaks coming into sunlight.—1870, February 9, 5.40. Sector seen faint, but easy. Streak *a* seen as a sharp, narrow, *bright* streak, running from the tip of the most northern shadow across to the N.E. border; it is nearly

parallel with a line through spots Nos. 1 and 4, but falls a little at the east end. Streak γ seen extending from a little S. of the middle of II E ψ^2, *faint*: 6 hours. Streak β seen running from spot No. 3 to the N. border.

1869, December 12.—Mr. Elger says, "I could make out a portion of the sector, but it was exceedingly ill-defined; the remaining part of the floor appeared to be of a uniform tint." Mr. Gledhill recorded the floor as light, $=0{\cdot}33$, and the sector faint, nearly as dark as the floor. The streak α seen with difficulty; the N.W. portion of the floor brightest. *The shadows of the west border had edges on the east very well defined, as if a narrow strip of light fringed them without nebulosity.* [This last remark appears to be incompatible with the idea of both spots and streaks being difficult of observation on account of the bad state of the earth's atmosphere; for the same observer, with the same instrument at the same time, describes the sector and α as difficult, while the shadows are so well defined as to exhibit diffraction fringes. Should the paucity of spots and streaks on this occasion not have been dependent on our atmosphere, then we have a different state of things to that which conduces to the apparition of spots when streaks are faint, and *vice versâ*.]

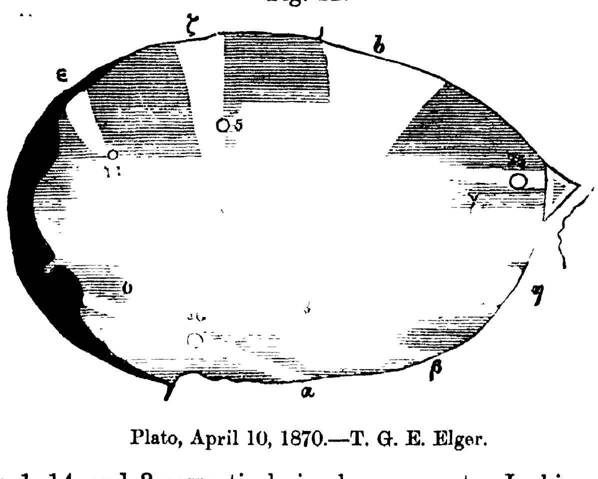
1870, October 3.—Mr. Elger recorded the sector as complete and faint, but in strong contrast with the dark floor; he remarks that it is unusual for him to see the sector at so early a period of illumination. Mr. Gledhill recorded the sector, with streaks α, β, γ, δ, ϵ, and ζ, as seen.

Summary.—Sun's altitude 7° 48′·1 to 11° 38′·2; tint of floor 0·39. Streaks generally visible—sector, γ, β, α, and arms of trident; they are mostly faint, but α was seen as a narrow *bright* streak on February 9, 1870.

Interval 36 to 48 hours.

1870, April 10.—In Mr. Elger's diagram of this date the connexion is unmistakable of the sector *b* with spot No. 4, also the N.E. end of the streak η with the same spot. The connexion of streaks ζ, ϵ, and β with

Fig. 12.



Plato, April 10, 1870.—T. G. E. Elger.

spots Nos. 1, 14, and 3 respectively is also apparent. In his remarks Mr. Elger says, "the east arm of the trident was traced through spot No. 5 to spot No. 1; it usually terminates near 5." He also says, "although faint,

the markings were easily traced; those on the east side of the floor, γ, η, and β, were decidedly the brightest; η was represented by a bright fan-shaped marking close under the east wall." [This is clearly the bright object described by Mr. Gledhill under date March 23, 1870, 36 to 24 hours (see *post*, p. 296), before sunset on Plato; and it is evident that it retained the quality, whatever it may have been, which contributed to its bright appearance during the intervening night. This quality appears to have affected the whole of the northern part of the floor; for we find, 36 to 24 hours before the previous sunset, the streak α described by Mr. Gledhill as "diffuse and extending up to the north border, and the following forenoon it could not be seen as a distinct sharp streak."—W. R. B.] Mr. Elger described the streaks α and "o" (seen as one) as ill-defined, especially the N.W. portion of it. The eastern and middle arms of the trident were the only streaks seen on the S.W. Mr. Gledhill, same evening, gives on a diagram the positions of the sector and streaks more or less similar to those given by Mr. Elger, and they both agree in placing spot No. 5 on the east edge of ζ. Mr. Gledhill describes all streaks as faint, and δ and θ (query ϵ), on tinted plate in 'Student,' p. 161, as meeting at a point two thirds the distance from the west border to spot No. 1. The east edge of sector is described as cutting the S.E. border a little west of the middle of the straight part of the S.E. border, and the west edge of sector cuts the south border nearly in the middle. Mr. Gledhill says, "the brightest part of the floor is the north and north-west, near the north border." α was not seen as a distinct sharp streak. "If," says Mr. Gledhill, "the east edge of the sector be produced to the north border, the darkest part of the floor lies to the east of this line. Is not this the line of fault marked in your key-plan (Report Brit. Assoc. 1861, p. 183) some years ago? and is not this the portion seen brightest near sunset at Plato on March 24, 1870?" Mr. Gledhill noticed that the most southern-pointed shadow (a blunt cone) from the west border was situated on and in the line of the streak θ (query ϵ). He does not mention the bright part of η seen by Mr. Elger, but gives the entire streak from spot No. 4.

1870, July 7.—Mr. Neison recorded the floor as dark, $=0{\cdot}66$; he says, "Never saw the floor so dark; spots very indistinct, not visible continuously." This is remarkable at so early an epoch, when the floor is generally described as light or bright. It is also remarkable that the spots should have been indistinct with so dark a floor. Mr. Elger remarked that the sector could just be traced.

1870, January 11, 5.36.—Mr. Gledhill records the floor as bright, $=0{\cdot}33$.

Determination of the position of sector.—See Report Brit. Assoc. 1871, pp. 66 & 67, and *ante*, p. 249.

Mr. Gledhill determined the S.E. extremity of the east edge of sector as cutting the S.E. border nearly in the middle of the straight wall to the south of II E ψ^2, and the south extremity of the west edge as cutting the south border at a point characterized by a line through spots Nos. 3 and 17 produced to the south border, *i. e.* spots Nos. 3 and 17 and the south end of the west edge of sector *align*. [On comparing this alignment with the plan from Mr. Gledhill's measurements (p. 66, Report 1871), it will be seen that it does not agree with the plan. There is abundance of evidence to show that the boundaries of the markings are variable in position.—W. R. B.]

Mr. Gledhill recorded the sector as but little brighter than the floor; in the darker parts streaks α, β, η, γ, δ, ϵ, ζ were well seen. The N.W. part of the floor was bright, and blended with the brightness of α. $7^h\ 0^m$. Streak β extends a little towards the S.W. of spot No. 3; streak η cannot be traced

clearly up to the border, but it is very bright close to the border. "It seems," says Mr. Gledhill, "as if it were thrown off by the bright lofty wall close to the north of II E ψ^2." [The dip of the floor to the border all round has been well determined. Does not this dip prevent not only the tracing of the streak, but its really extending as far as the border?] The sector passes on to spot No. 3, θ (?) meets ϵ about halfway from the west border to spot No. 1 (see *ante*, p. 247, fig. 1); they are both well seen, are sharp, and the dark space between them is sharply defined. On the same day Mr. Elger's record was as follows:—"The sector could be traced from spot No. 4, through No. 17, to the southern rim, and from No. 4 to the south of the triangular formation, II E ψ^2, on the eastern rim; but it was very faint and badly defined. The streak γ was not seen; but I remarked that the N.W. portion of the floor, especially near the border, was much *lighter* than the remainder. No traces of the trident."

The difference between the observations of Mr. Gledhill and Mr. Elger is mainly attributable to difference of aperture, with a probable difference of atmosphere; they both agree in the greater luminosity of the N.W. part of the floor in the neighbourhood of Webb's elbow.

1869, August 16.—See *ante*, p. 251.

1870, December 2.—Mr. Elger described the sector as very faint.

1870, November 2.—Mr. Elger recorded "faint traces of the sector." Mr. Neison remarked that the streak of light near spot 17 (the sector), was much darker, or rather less bright than usual.

Summary.—Sun's altitude 11° 38′·2 to 15° 23′·3; tint of floor 0·39, estimated from curve. Streaks generally visible—sector, arms of trident, and those on the northern and eastern floor, viz. Webb's elbow, ϵ, α, β, η, and γ.

This interval has been characterized by an extension of the sector as far as spot No. 3 on January 11, 1870, and of streak β beyond the same spot 3 on the same day. Were these extensions due to activity in group 3? It may be noted that streak α was well seen on the same day. Another interesting feature of the interval is the retention, during the night between sunset in March and sunrise in April, of the quality by certain portions of the floor by which they reflect light more strongly than under ordinary circumstances. The extreme faintness of the sector on November 2 and December 2, 1870, as well as its general faintness, is remarkable.

Interval 48 to 60 hours.

1871, March 1.—Mr. Gledhill recorded the floor as light, =0·33; streaks very faint, not well seen. Mr. Elger described them as generally faint, especially those on the southern part of the floor.

1870, May 10.—Mr. Elger speaks of the sector and streak γ as very bright and sharply defined, β much brighter than η. Trident faint, especially the west arm e. The lighter portion of the floor near the N.W. border was faint, especially at the west: it appeared to follow the curvature of the border of Plato. No trace of the elbow. Mr. Gledhill recorded the floor as "near medium" [registered =0·50], and the streaks brighter than last night [the 9th]. Mr. Gledhill mentioned his having seen α, from which it may be inferred either that the streak was really brighter than on the 9th (see *ante*, p. 273), or that the brightness on the northern part of the floor had declined in intensity. Mr. Pratt says: "b [the sector] and κ were of the streaks the most visible. The whole of the western end of the floor which was in light appeared covered by a continuous haze of brightness, the chord of the arc running nearly N. and S.; a faint glimmer of ζ was all that was possible."

The light portion of the floor Mr. Pratt described as extending from the west border as far as the streak g and Webb's elbow, as shown on the tinted plate in 'Student,' April 1870, p. 161.

1870, March 12.—Mr. Gledhill records the floor as "light, like the surface of the Mare Frigoris, 'medium.'" I have registered it as 0·42. He says, "all streaks seen except λ, which runs west from the spot No. 3." Of streak η he says, "η does not reach up to No. 4; it is a brush of light near the inner border just to the N. of II Eψ^2." [This certainly does not accord with η, but is much nearer the position of Pratt's l. There appears to be good evidence that the streaks slightly vary in extent and position.—W. R. B.]

1871, January 1.—Mr. Elger described the markings as "all faint," but did not specify them, except p, of which he says, "the new marking on the south side of the floor could be traced to the east of spot No. 5 (to about halfway between 5 and 17)." In his sketch December 4, 1870, Mr. Elger places spot No. 5 on the *west* edge of ζ.

1870, August 6.—Mr. Gledhill recorded the floor as medium, $=0·50$, and the streaks as faint and scarcely distinguishable from the floor. On the same evening Mr. Elger says, "Sector seen, but its borders were very badly defined." He also described the west portion of the floor as of an even light colour. This observation is greatly in accordance with Mr. Pratt's of May 10, 1870 (see *ante*, p. 277); the increase of light in both cases most probably depended upon the same agency.

1869, December 13.—Mr. Gledhill recorded the tint of floor as light, $=0·33$, the N. and N.W. portions being the brightest. The sector was well seen, extending as far as spot No. 3, with a bright base resting on the border; a and its vicinity, both to the south and up to the north border, bright and difficult to separate. It [this brightness] extends up to δ [and consequently includes κ and c]; δ widens as it approaches the border of Plato. [Does Mr. Gledhill mean that the light surface extended from the western arm of the trident on the N.W. and N. as far as spot No. 3? If so, the great northern streak would, in consequence of the sector and c being connected by the extension of the sector to spot No. 3, have nearly the same contour as given by Mr. Pratt on August 17, 1869, see *ante*, fig. 5, p. 252.] ϵ and ζ were well seen. Neither γ nor β were strong nor broad; η was the faintest streak on the floor.

Mr. Gledhill speaks of streak δ *widening* as it approached the border. This *widening* is by no means an uncommon occurrence; the sector is a familiar example, also the streak η has presented this phenomenon: both the sector and η proceed from spot No. 4, which of all the spots is characterized by the most remarkable appearances. Now this *widening* is closely in accordance with *ejecta* spreading from an orifice as it descends a surface slightly inclined.

Mr. Elger has shown (Report Brit. Assoc. 1871, p. 71) that the surface between spots Nos. 1 and 4 is depressed. Mr. Gledhill says: "I have never noticed that portion of the trident east of the spot No. 1; I am looking for it. I always see that portion of the trident in which spot No. 22 is situated as nearly in a line with spot No. 1 and II Eψ^2."

1870, October 4.—Mr. Elger saw the sector only; it was in strong contrast with the floor. He also exhibits the light border skirting the west side of the floor. Mr. Gledhill says:—"The west portion of the floor is the brightest; the line of separation runs through a point midway between spot No. 1 and the west border, and both ways to the north and south borders. This space includes Webb's elbow, c, the west end of δ, and S.W. end of ϵ." Similar observations of this light portion are recorded under May 9 and 10, the

latter by Mr. Pratt; also on August 6 by Mr. Elger. These observations are in contrast with those of Mr. Gledhill, 1869, December 13 (see *ante*, p. 278).

Summary.—Sun's altitude 15° 23′·2 to 19° 2′·0; tint of floor 0·41, estimated from curve. Streaks generally visible—the sector, arms of trident, and α, β, γ, with η, not quite so frequent, generally faint; but on Oct. 13 Mr. Gledhill saw the streaks stronger in the S.W. On May 10, 1870, the streaks were recorded as bright; and on October 3 and 4, 1870, the floor remained in a similar state, viz. *dark*, with the sector, although faint, strongly contrasted with it. The N.W. part of the floor does not appear to have attracted special attention on December 15, 1869, March 11 and 12, 1870, nor on January 1 and March 1, 1871.

Interval 60 to 72 hours.

1870, May 10.—See interval 48 to 60 hours, *ante*, p. 277.

1870, July 8.—Mr. Gledhill recorded the floor as bright, =0·33. The sector and streaks α, δ, and ε were seen as bright objects. He gives no record of a bright N.W. floor.

1870, January 12.—Mr. Gledhill writes, "Streaks all seen, but not so bright as last night." Same evening Mr. Elger writes:—"Tracing No. I. (see *ante*, p. 274, fig. 11) is from a drawing made about 7^h 25^m, which, as far as all the markings are concerned, scarcely differs from No. II. for December 1869. [In the tracing for Dec. 15, 1869, the one referred to (see fig. 13, p. 283), the streak γ is absent and the brightness on the floor adjoining the west border.] I noted the sector as the plainest and best defined; the three branches of the trident could just be traced, but they were very ill-defined; the fan [η] from No. 4 was plain, and the eastern portion (under the east rim) very bright as compared with the other markings. The streak γ was well seen, though faint; β could also be traced, but I was unable to see any signs of spot No. 32" [within or on it]. On the same evening, January 12, Mr. Pratt writes: "Sector *b* seen badly *without S.E. ray* [*l*], and connected as usual with streak *c* [agreeing in this respect with Mr. Gledhill's seeings], which appeared connected with the north border near *m* [this connexion is by Webb's elbow *i*]. Trident observed, excepting the junction of its arms: its stem seen. Contour of floor very similar to sketch of 1869, August 26." [On December 13, 1869, Mr. Gledhill's seeings were somewhat similar (see interval 48 to 60 hours, *ante*, p. 278).]

1869, August 17.—See *ante*, p. 252.

1869, November 14. Mr. Gledhill recorded the sector as "fairly bright," ζ and ε as broad and bright, and extending beyond and through spots Nos. 5 and 14; β faint, and α entirely east of spot No. 16, and from it α extends to the east border.

Summary.—Sun's altitude 19° 2′·0 to 22° 31′·3; tint of floor 0·45, estimated from curve. Streaks generally visible—sector, east and middle arm of trident; the others are not so frequent, but more of them are seen, and they are mostly brighter than in the earlier intervals. 1870, July 7 and 8, there appears to have been an absence of brightness in the N.W. part of the floor.

Interval 72 to 84 hours.

1870, April 11.—Mr. Elger recorded that all the markings seen on the 10th inst. were reobserved with the addition of the west arm of the trident (*e*); "*o*" was very hazy and ill-defined, η well seen. On the same evening Mr. Gledhill recorded the floor as medium, =0·50. The north floor at the

foot of the north border was brightest, especially at the N.W.; all streaks rather faint, especially the sector. Mr. Pratt speaks of "cloud" in the N.W. and S.W., where a ray from Anaxagoras appears to cross the floor, interfering with the *trident*, of which the *arm east of spot No.* 1 (ζ) and the west arm (e) were much obscured.

1871, March 2.—Mr. Elger records the markings as mostly faint. Webb's elbow and the streak a extending from spot No. 19 to spots 20 and 21 very distinct. The new marking, p (Mr. Pratt's), west of No. 5, faint but traceable.

1870, March 13.—Mr. Elger described the markings as faint and ill-defined; they were the same as seen on January 12, 1870. Mr. Gledhill recorded the floor as "medium or light, like Mare Frigoris," registered =0·42. Webb's elbow was well seen near the foot of the inner N.W. border.

1870, June 9.—Mr. Elger recorded the markings as faint and difficult to trace. The streak a on the N.W. part of the floor had the same nebulous appearance that it had on May 10. [Mr. Elger does not appear to have noticed a brightness of the N.W. part of the floor equal to that observed on May 9.]

1870, February 11.—Mr. Elger writes:—"All the markings shown on tracing No. II. (1870, January 14) were seen, but they were very faint. The three branches of the trident could just be traced." On the same evening Mr. Gledhill says:—"Streaks α, β, γ, δ, ϵ, ζ are well seen, as also the sector. I see a faint streak μ just above the west end of α and parallel with it; this streak, if produced eastwardly, would pass just north of spot No. 3 (see fig. 16, *post*, p. 286). The streak λ is seen easily, it is the faintest; streak β extends a little to the west of spot No. 3. There is a strong brush of light from the border just north of II E ψ^2, from which a faint streak runs up to spot No. 4." [Is this Mr. Pratt's l? its direction agrees, but its locality is rather too far to the north. See interval 48 to 60 hours, 1870, March 12, *ante*, p. 278.]

1869, December 14.—Mr. Elger recorded α and its continuation "o" as the brightest and best defined on the floor, and he shows Webb's elbow in contact with the N.W. border. Mr. Gledhill mentioned the bright floor connecting α and δ, but without a distinct streak; he recorded the floor as light, =0·33, and all the streaks as well seen, η the faintest, and the extension of the sector to spot No. 3 not easy. Mr. Elger says:—"The sector I noted as faint and difficult to trace; the middle prong of the trident appeared to be the brightest on the S.W. side of the floor; it could be traced as far as spot No. 14." Mr. Pratt noticed the trident shaded off round spot No. 1, the sector nearly divided between spots Nos. 3 and 4, and γ in contact with the sector.

Summary.—Sun's altitude 22° 31′·3 to 25° 49′·5; tint of floor 0·49, estimated from curve. Streaks generally visible—sector, trident, and the N.E. streaks α, β, η, and γ mostly faint; λ and μ were observed on February 11, 1870; and α, with its continuation "o," was recorded as the brightest and best defined on the floor on December 14, 1869.

Interval 84 to 96 hours.

1870, March 13.—See interval 72 to 84 hours, see above.

1870, December 4.—Mr. Elger writes:—"The marking connecting the middle and east arms of the trident, which was, I believe, first seen by Mr. Pratt last spring, I found a very easy object, fully as bright as the brightest portions of the trident; it follows the curvature of the south border, and,

crossing the east arm of the trident, terminates about halfway between the latter and the west limit of the sector. During the May and June lunations I had faint glimpses of it, but it was then a more difficult object than it is now."

1870, September 6.—Mr. Gledhill recorded the floor as dark, =0·66. Streaks very bright and well seen.

1869, November 15.—Mr. Pratt has the following remarks on the light-streaks:—"The trident and sector were both reobserved *complete*, with the exception of the shading off round spot No. 1. (See interval 72 to 84 hours, *ante*, p. 280.) *A considerable addition was also well observed.* 1°. The sector appeared widened out between spots Nos 3 and 4. 2°. The N.E. streak was traced of the form sketched, and in contact with the border. [This appears to be the *earliest* instance of the greater reflective power of the northern part of the floor, which is independent of libration, inasmuch as both on August 26, when the streak was quite free from the border, and on this day, when in contact with it, the moon had south latitude. It is also independent of illuminating angle, as it was most extensive and brightest at an interval of 24 to 36 hours (see that interval, May 9).] 3°. A tongue of light jutting out from the border on the north of B. and M.'s ζ, *i. e.* the high rock at the east of Plato. [This is the streak η, first recorded by Mr. Gledhill on October 19, 1869.] 4°. The sector [or streak] on the north of spot No. 3 spread out as far as the border, and enclosing spots No. 20 and 21. 5°. The streak c made another contact with the border near spot No. 16 [this contact is Webb's elbow]. The streak was connected with the N.W. arm (e) of the trident, being continued beyond its usual termination near spot No. 13, and could be traced to about halfway towards the middle arm (ϵ), beyond which it was quite invisible." [On the next luni-solar day, December 13, 1869, interval 48 to 60 hours, the same general distribution of the streaks, with the extension of the lighter surface to the north border, was seen by Mr. Gledhill (see *ante*, p. 278).] In Mr. Gledhill's observations of November 15, he does not mention the streaks separately, but gives on the diagram the sector b diverging from spot No. 4. He does not indicate the widening out between spots Nos. 3 and 4, as seen by Mr. Pratt. He gives γ and β both up to the border, also the streaks a and c, but does not give the continuation into the trident, which it appears he did not observe except the streak δ.

1869, October 16.—Mr. Pratt recorded the junction of the trident as difficult, especially so just west of spot No. 1; the sector and c much the brightest.

Summary.—Sun's altitude 25° 49′·5 to 28° 54′·3: tint of floor 0·52, estimated from curve. Streaks generally visible—the sector and trident, the N.E. streaks less frequent; trident seen complete with stem on October 16 and November 15 by Mr. Pratt.

Interval 96 to 108 hours.

1870, April 12.—Mr. Gledhill recorded the floor as dark, =0·66; he described the streaks as all brighter than on the 11th. Mr. Pratt on the same evening recorded the sector as very easy; also l, κ, c, α, and β; η was seen, not as a streak, but a *tongue* of light running from the border towards spot No. 4. The streak n (very rarely seen) was observed extending from spot No. 1 to streak κ; ζ and ϵ, the eastern and the middle arms of the trident, were difficult; the *western arm* of the trident was very faint. The whole area bounded by spots Nos. 14, 1, and 16 with the western border ***very hazy.*** Crater G on the exterior N.W. slope well defined at times.

1871, March 3.—Mr. Gledhill recorded the floor as dark, $=0\cdot66$; the streaks bright. Mr. Pratt recorded the floor as medium, $=0\cdot50$. This evening he witnessed an unusual display of streaks, as many as fifteen, which he arranged in order of brightness thus:—the sector, the curved streak κ near the north border, the streak β from the triple group of spots Nos. 3, 30, and 31, the streak α from spot No. 19 to the N.E. border, the middle arm of the trident ϵ, the N.W. curved streak c, Webb's elbow i, the eastern arm of the trident ζ, the N. bifurcation of the western arm δ and the southern bifurcation θ, the narrow streak from S.W. to N.E., n, very rarely seen, the short arm l of the sector towards the S.E. also very rarely seen, the streak γ from spot No. 6, the streak η from spot No. 4, and the *new* streak p from spot No. 5 to spot No. 17 (this, Mr. Pratt remarked, was *seen easily* joining the eastern arm of the trident and the sector from a point opposite to No. 5 to a point closely south of No. 17; it was narrowed about the middle). The streaks β, α, and l were far brighter than in their normal state.

1870, May 12.—Mr. Gledhill recorded the floor as dark, $=0\cdot66$, and the streaks bright. He does not mention the sector; but from his remark that *all* were seen, and Mr. Elger regarding it as "very bright," I have inserted it.

1870, March 14.—Mr. Elger's record is as follows:—"The markings were not well seen; the eastern arm of the trident was the brightest, and could be traced from the south rim of Plato to spot No. 1, passing to the west of spot No. 5. The streak γ was very plain; the rest of the markings were very faint and difficult to make out." Mr. Elger further says:—"In spite of the haziness of the sky, the markings and minute details of the northern part of the *Mare Imbrium* were seen with unusual distinctness." [This is another important testimony to the unequal visibility of objects, and would indicate that the indistinctness of the markings on Plato was dependent upon some agency more immediately connected with the moon itself.] About an hour earlier on the same evening Mr. Pratt observed Plato, and recorded the markings as rather easily visible. He observed all he had seen before, which were of almost the identical forms of 1869, November 15 (see interval 84 to 96 hours, *ante*, p. 281). He also recorded two bright streaks from *Anaxagoras*, which crossed the N.W. border, the streak c, and the N.W. arm of the trident, and somewhat confused at first sight the light-markings on the floor (see *ante*, p. 280).

1870, June 10.—Mr. Elger recorded the sector and the streak γ as the brightest markings; η and β were faint, especially η; β, though faint, could be traced up to spot No. 3. The eastern portion of α was bright and well defined; the west portion had a hazy appearance, as, indeed, had the whole of the N.W. portion of the floor. Mr. Gledhill described the streaks and spots as bright, and seen as on June 9; he recorded the floor as dark, $=0\cdot66$.

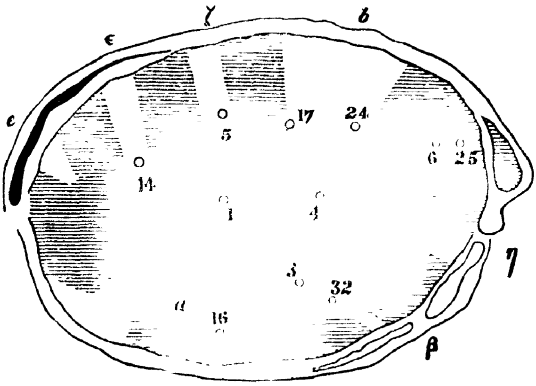
1870, February 12.—Mr. Gledhill recorded the floor as "medium, but nearer dark." I have registered it at $0\cdot55$. Streaks all seen, except the two faint ones λ and μ; ϵ, the middle arm of the trident, brighter than either ζ or δ; α very broad and bright; β and γ well seen; η not distinct near spot No. 4, but bright near the border of Plato.

1870, August 8.—Mr. Gledhill recorded the floor as rather dark, $=0\cdot70$. Streaks not very bright, but well seen.

1869, December 15.—Mr. Elger writes:—"The markings on the floor were much more distinct than on the 14th. The prongs of the trident (ζ, ϵ, e), the sector (b), a fan of light extending from spot No. 4 to the east rim (η), and the brush (β), on which spot No. 32 is situated, are shown on fig. 13.

Mr. Elger's diagram of this date fully confirms the observations by Mr. Gledhill of the streaks β and η, and their parallelism with α in September and

Fig. 13.



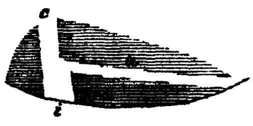
Plato, Dec. 15, 1869.—T. G. E. Elger.

October. I believe this to be Mr. Elger's first observation of these streaks. Taking into consideration the difference of apertures, were they first within reach of the smaller aperture of 4 inches on this day (December 15)? If so, did they become brighter during the interval that elapsed since Mr. Gledhill first saw them? At the close of the October (1869) observations, Mr. Gledhill furnished the following information:—" Parallel streaks on N.E. floor. I have gone over all my observations, and find that γ (see fig. 9, *ante*, p. 263) has always been seen except at sunrise and sunset. β appears in my observations for the first time September 25, 1869, about 11 hours. At this time the light sector passed beyond spot No. 4, and had its apex about spot No. 3. It was also seen at this point again on October 21 at 12 hours." [Was there any connexion between the sector extending as far as spot No. 3 and the streak β emanating from the same spot, as if the spot or group had been in eruption? The very short extension of the streak β seen once or twice by Mr. Gledhill beyond spot No. 3 towards the S.W. is curious, as if it were an outflow in that direction which could not proceed in consequence of the rising of the ground.] Mr. Gledhill further remarks:—" I saw β a few hours before sunset on Plato on the 27th of September, 1869, and also the sector and some other streaks. The streak η was first seen by me about 11 hours on October the 19th, 1869. It comes from that fine summit on the crater-wall (the rock ζ of B. and M.) which casts the long shadow on the plain at sunset. The streak β I think comes from a portion of the inner slope, which is often highly illuminated; β and η are nearly always seen now. [Mr. Gledhill appears to regard these streaks as emanating from the wall. Is it not more likely that η emanates from spot No. 4, and β from spot No. 3?—W. R. B.] On the evening of December 15, 1869, Mr. Gledhill recorded the streak β as fairly bright, and η as faint near spot No. 4, with a broad brighter base, which is, as mentioned elsewhere, quite in accordance with phenomena of eruption from spot No. 4. I have made the following remarks on the form containing Mr. Gledhill's observations:—" η, which, if I remember rightly, Mr. Gledhill first saw as a *narrow streak*, to-night is described as broad, with bright base, faint near spot No. 4. Mr. Elger on the same evening described a 'fan' of light from

spot No. 4. He has not mentioned it before. Mr. Elger gives β with the spot No. 32, discovered by him this evening." Mr. Gledhill's record of the remaining streaks observed by him is as follows:—" ϵ and ζ bright, broad; α, β, γ, δ fairly bright; ζ extends up to spot No. 4? ; ϵ extends as far north as ζ." He agrees with Mr. Elger in recording the "streaks as brighter than last night," the 14th. He does not mention the sector; but I suppose he saw it. In speaking of ζ extending to spot No. 4, does he refer to η?

1870, October 6.—Mr. Gledhill recorded the floor as medium, $=0{\cdot}50$; the streaks very bright. Mr. Elger, the same evening, described them as all faint, especially on the east side of the floor. Webb's elbow and c he described as plain: a sketch is given of the junction much the same as it was seen on August 11, 1870 (interval 168 hours to meridian, see fig. 18, *post*, p. 289); the western strip of light on the floor appears to have subsided since October 4, as observed on May 10, compared with May 9, 1870 (see *ante*, pp. 273 & 277).

Fig. 14.



1870, Oct. 6.—T. G. E. Elger.

Summary.—Sun's altitude 28° 54'·3 to 31° 42'·7; tint of floor 0·54, estimated from curve. Streaks generally visible—sector, trident, and N.E. streak. The trident with stem was seen complete by Mr. Pratt on March 14, 1870. The streak n, which is very rarely seen indeed, was observed on April 12, 1870, and also on March 3, 1871. The streaks were mostly bright.

Interval 108 to 120 hours.

1870, May 12.—Mr. Elger recorded the sector and streak γ as very bright and well defined; β brightest near spot No. 3, and faint at border. The three arms of the trident, ζ, ϵ, e, faint, but easily traced; the floor noted as very dark between ϵ and e. The projection from Webb's elbow, c, seen during the April lunation, although plainly seen, could not be traced so far to the south as before, and was not so sharply defined; indeed all the *west* portion of the N.W. marking (*i.e.* the brightness in the N.W.) was hazy. [Haziness on the W. and N.W. part of the floor was noticed on April 11, 1870, by Mr. Elger. On April 12, 1870, by Mr. Pratt, who described it as *very hazy*. On June 10, 1870, by Mr. Elger.] The streak α east of spot No. 16 was very bright and well defined, and Webb's elbow was very evident. The localities of spots Nos. 33 and 35 were the brightest. On the same evening and interval, Mr. Pratt described the sector as but faintly seen, and with the very same aspect as his first view of it, viz. a streak sloping more N.W. and S.E. than usual, its western edge quite straight, its eastern edge slightly curved and fan-shaped; all other streaks invisible.

1870, January 14.—Mr. Elger writes:—" The markings were at times very distinct, the east portion of γ unusually so. I was unable to make out Webb's elbow. The streaks η, β, γ, the sector, and trident were all distinctly seen. I much regret that the long spell of cloudy weather prevented me from observing the markings after the 14th instant, as I think those on the east side of the floor (γ, η, β) were visible much sooner after the first quarter during this lunation than they were during the last. [Had they become brighter? See Interval 96 to 108 hours, 1869, December 15, *ante*, pp. 282–284.] There appeared also to be something abnormal about spots Nos. 1, 3, 4, 5, and 17. Spots Nos. 6, 24, &c. I was unable to make out, although they were seen on the 14th of December, 1869.

1870, September 7.—Mr. Gledhill recorded the floor as dark, $=0{\cdot}66$; streaks all very bright.

1869, November 16.—Mr. Gledhill recorded the floor as very bright, =0·10; he says: "I never saw the floor so bright; streaks very bright indeed, definite and easy. I have drawn them as I saw them. That drawn through No. 5 does not quite reach spot No. 1. Streaks θ and δ [the bifurcation of e] meet halfway between the extremity of δ (which originates at the foot of the inner slope in a bright elevation on the floor close to the foot, probably B. and M.'s mountain-peak δ) and spot No. 1."

1869, October 17.—Mr. Gledhill recorded the floor "as dark as the south part of the Mare Serenitatis (?), registered as medium, =0·50." He also recorded a well-seen streak which covered spots Nos. 13, 19, and 16, parallel to the streak β, which, if produced to E.N.E., would cut the north border of crater A outside Plato. The western portion is designated "o," the eastern α.

Summary.—Sun's altitude 31° 42'·7 to 34° 11'·5; tint of floor 0·57, estimated from curve. Streaks generally visible—the sector and N.E. streaks; arms of trident not so frequently seen. The streaks were mostly bright, and especially so on November 16, 1869.

Interval 120 to 132 hours.

1871, March 4.—Messrs. Gledhill and Neison record the floor as dark, =0·66. Mr. Neison speaks of the N.W. and S.E. portions of the floor as indistinct from broken light and streaks (see Report British Association, 1871, p. 81); and Mr. Gledhill speaks of the arms of the trident being very broad and diffuse.

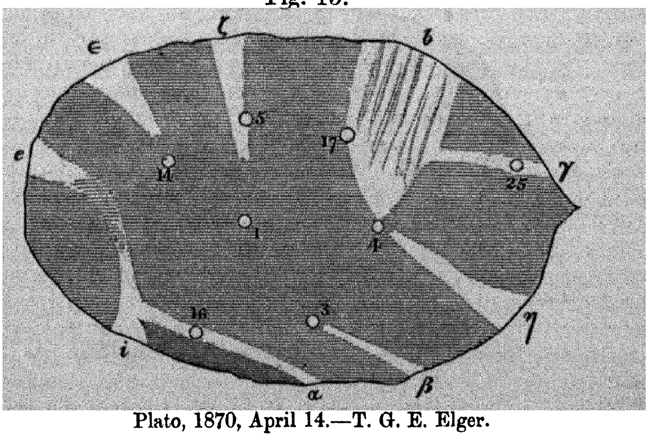
1870, June 11.—Mr. Elger could only see the sector and the three arms of the trident, all faint. The same evening Mr. Gledhill recorded the floor dark, =0·66; streaks bright.

Summary.—Sun's altitude 34° 11'·5 to 36° 17'·5; tint of floor 0·60. Streaks generally visible—sector, arms of trident, and N.E. streaks except η.

Interval 132 to 144 hours.

1870, April 14.—Mr. Elger described the streak β as very plain and bright, brighter than γ. The middle, ϵ, the brightest portion of the trident;

Fig. 15.



Plato, 1870, April 14.—T. G. E. Elger.

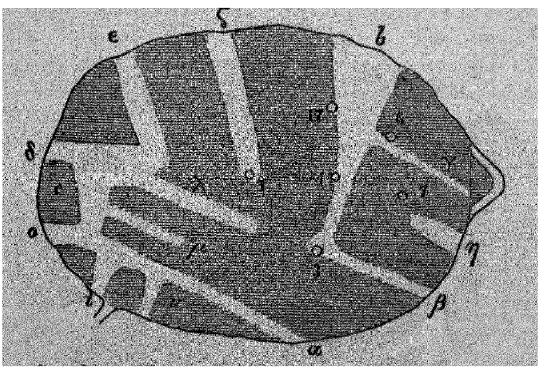
η plain, brightest near the border, directed from the border towards spot No. 4; diminishing in breadth as it approached No. 4, it could be traced

almost up to it. The sector b did not appear to be equally bright, but seemed to consist of light-streaks directed towards spot No. 4 (see fig. 15, p. 285). The most interesting feature observed this evening was a projecting arm from the west end of a, apparently a continuation of Webb's elbow across the end of a. Mr. Elger speaks of it as very plain, and occupying a position a little east of the curved streak c, which is far from being constant in its appearance, even if it should have a permanent character. On this ray or projection I made the following remark when I received the information:—"It appears to be a lateral *translation* towards the east of c, the portion of the curved streak west of spot No. 16, nearly in a line with Gledhill's θ;" and I further said, "this has much the *direction* but not the *position* of Elger's h in the tinted plate of the 'Student,' April 1870, p. 161." Mr. Gledhill writes the same evening:—"All streaks are very bright, γ narrow and sharp, η not well seen far from the border, Webb's elbow conspicuous."

1870, May 13.—On this day Mr. Pratt saw no less than 42 objects on the floor of Plato, 26 spots and 16 streaks. The stem of the trident was well seen, also the streak η as a fan or tongue. For Mr. Pratt's remarks on the streaks, see Report British Association, 1871, pp. 88–91. On the same evening, May 13, Mr. Elger recorded the streak γ as very bright; η and β faint, η the faintest on the east side of the floor; the three arms of the trident faint; a bright and well defined; c (the projection from Webb's elbow) nearly as bright as at last lunation, very bright at the position of spot No. 19; sector very bright and well defined, a dark zone between its base and the border of Plato. [This dark zone is very unusual.]

1870, January 15.—At 6ʰ Mr. Gledhill recorded "all streaks bright;" the brightest were a and β; all others (γ, δ, η, ζ) were seen well; γ, which was seen as a narrow sharp bright streak, not broader than spot No. 17, cut II $E\psi^2$ a very little south of its middle point. The bright elbow (i) on the N.W. floor, at foot of slope of wall, was well seen. At 10ʰ Webb's

Fig. 16.



Streaks on Plato, 1870, January 15.—J. Gledhill.

elbow was seen to throw off an arm to the south, towards the streak δ [this seems to have been a portion of the streak c]. From 12 to 13 hours, Mr. Gledhill says, "β is fine and bright, but I cannot trace it beyond spot No. 3. The sector is very bright; it passes beyond spot No. 4 and meets streak β to

the east of spot No. 3. The elbow on the N.W. border, just to the S.W. of the end of the ridge which runs from the wall of Plato out to the N.W., is well seen; it sends out an arm to the south, which is forked. The northern prong, which extends to the west border, is the extension 'o' of the streak a, and the southern prong c meets the streak δ west of the point of junction of the streaks δ and ϵ." Mr. Gledhill further says, "I also see another faint streak sent off from the long northern streak a up to the border; it cuts the border just east of the exterior ridge." [This faint streak is marked ν; it has not been reobserved.] "A narrow faint streak runs from a point a little to the S.W. of spot No. 3, parallel to a, and joins the streak δ between its junction with c and ϵ" [this streak is marked λ]; "there is also a still fainter and shorter streak (μ) just south of a, or rather its continuation, "o." I tried to see β and the streak λ as a continuous streak, but could not; neither did I find that they were *quite* in the same S.W. direction, but they were very nearly so indeed. η could not be traced quite up to spot No. 4; on the border it was a large square bright streak resting against the foot of the terrace (lowest) of the inner N.E. wall."

The streaks λ and μ, discovered this evening, have been observed only by Mr. Gledhill; it is probable that they are too faint to be seen with smaller apertures than 9 inches; they have been seen occasionally between January 15, 1870, and March 6, 1871.

1869, August 20.—See *ante*, p. 253.

1870, November 6.—Mr. Gledhill recorded the floor as dark, =0·66; streaks very bright. Mr. Elger says of them, "all faint and difficult to trace, those on the east side of the floor especially."

Summary.—Sun's altitude 36° 17'·5 to 37° 57'·8; tint of floor 0·62, estimated from curve. Streaks generally visible—the sector, east and middle arms of trident, and the N.E. streaks a, β, γ, and η; the whole variable in brilliancy. On January 15 and May 13, 1870, more streaks were seen than usual, especially on May 13.

Interval 144 to 156 hours.

1871, March 5.—Mr. Elger described the markings as all faint.

1869, July 22.—Mr. Gledhill could see *nothing* on the floor, which he recorded as very dark.

1870, August 10.—Mr. Neison recorded the floor as medium, =0·50, and Mr. Gledhill recorded it as dark, =0·66; he described the streaks as bright, and η not far from the border, as usual.

1869, December 17.—Mr. Gledhill recorded the floor as dark, =0·66: he described the sector as bright, and streak a as very bright; β and γ as bright, δ, ϵ, and ζ less bright, but not equally so; η the faintest, but bright near the border of Plato. Mr. Gledhill describes a luminous broad patch, which, starting from the inner border of Plato, about B. & M.'s object ϵ [the most northern peak on the west border], joins the streak a; it also sends off a luminous streak to δ. The luminous patch is brighest and broadest near the foot of the inner slope. [The broad patch is most probably Webb's elbow, and the streak to δ is c.—W. R. B.]

1870, October 8.—Mr. Elger recorded the markings as generally faint, except a, Webb's elbow, and c. β and γ were much brighter than η; the trident faint.

Summary.—Sun's altitude 37° 57'·8 to 39° 9'·2; tint of floor 0·64, estimated from curve. Streaks generally visible—sector, trident, and N.E. streaks; they alternated in brightness.

Interval 156 to 168 hours.

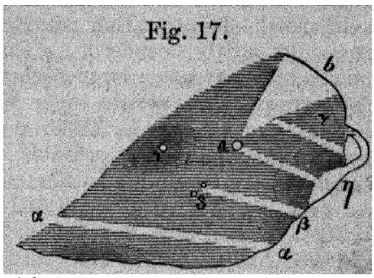
1870, May 14.—Mr. Elger recorded the markings all faint; a and Webb's elbow well seen. At the point of junction of a, c, and i (qy. position of spot No. 19) the floor was very bright. Mr. Gledhill on the same evening recorded the floor as dark, $=0{\cdot}66$. Streaks bright, sector and a the brightest; elbow well seen; λ and μ were not seen.

1869, August 21.—See *ante*, p. 253.

1870, December 7.—Mr. Elger recorded all the markings as faint, except κ and p. Mr. Gledhill recorded the floor as dark, $=0{\cdot}66$.

1870, September 9.—Mr. Elger recorded η and β as very faint.

1869, October 19.—Mr. Gledhill recorded the floor as dark as the south part of Grimaldi; it is registered as $=0{\cdot}70$. Mr. Gledhill furnished the annexed sketch of the streaks a, β, η, and γ, with the sector, unaccompanied by any remarks; it would appear from this that the whole of the S.W. part of the floor was in some way obscured (see pp. 255 to 262). Mr. Pratt's remarks on the same evening confirm this idea; he says, "Trident near spot No. 1 *invisible*, only the ends of the arms detected with difficulty." He also specifies the positions of the *dark localities* on the floor: "darkest near m, i. e. the mountain on the north border." [It was this locality which in May 1870 was noticed to be very light, see pp. 273 and 277.] The next darkest area was closely S.W. of B. and M.'s rock ζ, next above it, S.W. of spot No. 1, and the lightest of the dark spaces N.W. of the rock ζ. We have here four areas characterized by a darker tint, the floor itself being registered as more than ordinarily dark, one of the darker spaces being accompanied by an obliteration of nearly the whole of the trident. The localities of the darker areas are shown on the annexed engraving, containing Mr. Gledhill's streaks.



Plato, October 19, 1869.—Gledhill.

Summary.—Sun's altitude 39° 9′·2 to 39° 50′·5; tint of floor 0·65, as estimated from curve. Streaks generally visible—the sector, east and middle arms of trident, also the N.E. streaks a, β, γ; η not so frequent.

Interval 168 hours to meridian passage.

1870, April 15.—Mr. Gledhill recorded the floor as dark, $=0{\cdot}66$. Of the streaks seen, the sector and a and β are described as very bright. The same evening Mr. Elger described the sector and γ as the brightest markings on the floor; η, β, and trident very faint. The projecting arm (registered as c, see *ante*, p. 286) observed on the 14th appeared brighter this evening, and extended further towards the west arm of trident, which it almost touched (compare with Mr. Gledhill's sketch on January 15, 1870, *ante*, p. 286); its direction formed an obtuse angle with the direction of the west arm and with the streak a; the streak "o" absent.

1871, March 6.—Mr. Gledhill recorded the floor as dark, $=0{\cdot}66$. The streaks and sector bright and well seen, the two fainter streaks λ and μ included. These streaks have been seen on seven occasions before meridian passage.

1870, June 13.—Mr. Gledhill recorded the floor as dark, $=0{\cdot}66$; the streaks and spots bright, but not well seen. Mr. Gledhill has the following

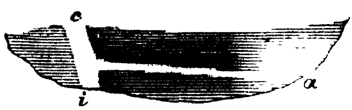
remark:—"The effect of a low power on ζ and ϵ (the east and middle arms of trident) is to show their southern extremities as bright hazy spots, and to hide their character as lines of light; a higher power shows the whole line as a nearly (or quite) uniformly bright streak."

Under this interval and date I have the following memorandum:—"It is a little remarkable that the streaks β, η, and, still later, γ should exhibit such variations as to accord with a decrease of brightness, becoming lost to Mr. Elger, but still lingering in the Halifax refractor. With regard to the tint of the floor, observation has established that it becomes darker under a high sun. Three hypotheses may be suggested in explanation:—*First*, Will the heating of a bare surface produce a darkening of that surface? *Second*, Increase of angle of illumination, we know, occasions a darkening of the vegetable covering of the earth: is it so with the moon? *Third*, Can there exist within the mountainous enclosure of Plato *absorptive* clouds the results of vaporization by long-continued sunshine?"

1869, July 23.—Mr. Gledhill recorded the sector as fairly well defined.

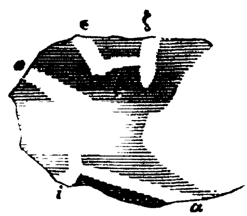
1870, August 11.—Mr. Elger described the markings on the east side of the floor η and β as very faint; the sector and γ were not so faint; the three arms of the trident, ζ, ϵ, and e, were plain; a, with Webb's elbow, were seen, as in April and May last, very distinct. The drawing gives the elbow and the part of c as forming a sharp angle with a.

Fig. 18.



Plato, 1870, Aug. 11.—T. G. E. Elger.

Fig. 19.



Plato, 1870, Oct. 9.—T. G. E. Elger.

1869, September 20.—Mr. Gledhill recorded the floor as dark, = 0·66, not quite so dark as the south part of Grimaldi; the sector easily seen. Same evening Mr. Elger registered the N. boundary of the sector as extending from spot No. 4, just past No. 7, to the east border. This appears to have been an extension of the sector, including the streak γ. For Mr. Elger's drawing of this day, see history of streak a, p. 263, and for remarks, see *ante*, p. 262.

1870, October 9.—Mr. Elger recorded the sector as plain, η faint, trident faint. "I again suspect," says Mr. Elger, "the connexion between the eastern and central arms of the trident observed by Mr. Pratt." Mr. Elger gives a sketch of a and Webb's elbow, with c in a line with the elbow, joining e, the west arm of the trident. The streak c, from Webb's elbow to the west arm of trident, is curved, the concavity towards the west border (see Interval 168 to 156 hours, *post*, p. 291). Nothing appeared to occupy the area between the border and streak except the plain floor; the streak "o" entirely absent. See intervals 132 to 144 hours, and 168 to meridian, *ante*, pp. 285, 288).

Summary.—Sun's altitude 39° 50′·5 to 40° 0′·0; tint of floor 0·66, estimated from curve. Streaks generally visible—the sector, the middle arm of trident most frequent, the eastern arm next, and the western arm

but seldom; the streak α more frequent than γ, β, or η. Most of the observations during this interval have shown the N.W. part of the floor in *proximity* with the border as destitute of streaks.

Interval meridian passage to 168 hours.

1870, March 17.—Mr. Gledhill recorded the floor as dark, = 0·66; he described the sector and streak α as easy objects, bad as was the night; the southern streaks were faintest, α and the sector brightest, then came η, γ, β.

1870, July 13.—Mr. Gledhill recorded the floor as dark, = 0·66; streaks very bright.

1870, September 10.—Mr. Elger recorded the sector and trident (three arms, ζ, ϵ, e) as very distinct, η scarcely discernible, and β brightest near the rim.

Summary.—Sun's altitude 40° 0′·0 to 39° 50′·5; tint of floor 0·67 to 0·66. Streaks generally visible—the sector and the east and middle arms of trident; the N.E. streaks less frequent.

Interval 168 to 156 hours.

1870, April 16.—Mr. Gledhill recorded the floor as dark, = 0·66; the streak α is described as bright and sharp. The same evening Mr. Elger writes:—"The markings appeared as on the previous night, with the exception of the projection from Webb's elbow (c), which I could not see." This is noteworthy, as on the 14th and 15th it was evidently increasing, now it seems to have suddenly disappeared; it does not appear to have been observed by Mr. Gledhill.

1871, January 7.—Mr. Elger recorded the markings all plain. The curved marking on the N.W. side of floor appeared exactly as shown in the 'Student,' April 1870, p. 161; the elbow i was distinctly seen. The new marking p was also well seen; spots Nos. 5 and 17 were connected by it: at times γ seemed to be a prolongation of it; it could not be traced through the sector.

The observation by Mr. Elger of κ and c with Webb's elbow, being exactly as given in the 'Student,' is interesting, especially as contrasted with the observations, also by Mr. Elger, of the prolongation of the elbow at a sharp angle with α (see *ante*, pp. 284, 289), from which it may be inferred that the streak is variable in position; and this gives further countenance to the conclusion that the N.W. portion of the floor is the most variable.

1870, August 12.—Mr. Pratt recorded the floor as *very dark*, Mr. Neison recorded it as dark. Mr. Pratt says:—"In moments of best definition the area comprised between spots Nos. 19, 1, and 4 and the northern and north-east rim was not nearly so well displayed as the rest of the floor, giving a strong impression of an obscuring medium existing there. The dark parts of the floor were darker near the rim."

1869, December 19.—Mr. Gledhill recorded the floor as dark, = 0·66; the sector very bright, and, after spot No. 1, the most striking object; α bright, δ, ϵ, ζ less bright; the prolongation of the sector to spot No. 4 fairly seen.

1869, September 21.—Mr. Gledhill recorded the floor as not so dark as the extreme south part of the floor of Grimaldi. Of streak c he says, "Spots Nos. 13, 19, and 16 are well seen, a streak of light connects them; it is a thick, dense streak, not faint and diffuse." The sector he describes as "bright, permanent."

1869, November 19.—Mr. Gledhill recorded the floor as dark, = 0·66. In addition he gave the following remarks:—"The sector bright and well de-

fined; as usual, of all the streaks α is always brightest; β is one of the brightest, but less so than α; γ is similar; η is bright and mostly well seen; ζ, ϵ, θ, and δ are always the faintest and broadest; ϵ and ζ are almost always seen, δ not always; that portion of α which lies to the west of spot No. 16 is not always seen" [this answers either to "o" or c]. Mr. Gledhill described and figured a short streak from the N.W. border very bright. On this I remark:—"The elbow of light tint described by the Rev. T. W. Webb as seen by him on Oct. 24, 1855 (see monogram of the Mare Serenitatis, p. 13), was well seen (and very bright) by Mr. Gledhill, 1869, Nov. 19, moon's latitude 4° 10′ ± S. On the 16th the moon's latitude, 5°, was more favourable for seeing it; but it does not appear, from Mr. Gledhill's observations, that it was then visible." See Mr. Gledhill's remarks on the streaks γ, β, and η, *ante*, p. 283.

It would appear that, so far as the streaks are concerned, the N.W. part of the floor exhibits the greatest amount of variation. Looking at Mr. Gledhill's diagram of November 19, and taking into consideration the general structure of the floor, we have in the S.W. the arms of the trident radiating from spot No. 1; in the S.E., the sector fan-shaped, the sides radiating from spot No. 4; in the N.E., β specified by Mr. Gledhill as one of the brightest streaks from spot No. 3, and α, β, η, and γ more or less parallel. Now bearing in mind that Plato has suffered dislocation from a fault from N.W. to S.E., that spot No. 1 is opened upon the highest part of the floor, and that spots Nos. 3 and 4 occur on the N.E. slope from the fault, it is not a little significant that the directions of the streaks are from higher to lower ground. Mr. Pratt suggests that the light-streaks are coincident with formations analogous to "spurs" from the chief centres of the residual activity on the floor (see Report Brit. Assoc. 1871, p. 95).

1869, November 19.—On this evening Mr. Gledhill observed the streak α and its continuation "o"; he also saw, forking from the locality of spot No. 16, the curved streak c, convex to the west border (see *ante*, pp. 263, 264, 285, 289). On contrasting Mr. Elger's and Mr. Gledhill's sketches of Sept. 20 and 25 respectively with Mr. Gledhill's of Nov. 15 and 16, and especially of Nov. 19, the existence of c and "o" as separate streaks is undeniable. On Sept. 20 and 25 "o" was distinctly recorded by two independent observers; it was also recorded on Oct. 25, 26, and 27 by Mr. Gledhill. On Nov. 15 it was not seen by Mr. Gledhill, nor on the 16th, the streak c passing over and beyond spot No. 13. On Nov. 19 there was a great development of light-streaks, the N.W. part of the floor exhibiting the curved streak c, with "o" and α and Webb's elbow in contact with the N.W. border. Mr. Pratt recorded the N.W. streak making a contact with the N.W. border, near spot No. 16, on Nov. 15.

1870, October 10.—Mr. Elger recorded γ and β as plain, η faint; the connexion by p between the centre (ϵ) and eastern (ζ) arms of trident seen. Trident and markings on N.W. side of floor as on the 9th of October. Spot No. 5 is recorded as seen on the east edge of the east arm of trident (see *ante*, pp. 254 and 275). Messrs. Pratt and Neison recorded the floor as "medium," and Mr. Gledhill recorded it as "very dark." The lighter tint, as seen by Messrs. Pratt and Neison, is exceptional. Mr. Gledhill mentioned that the sector was composed of bright lines radiating from the apex to the base (see *ante*, p. 285). Mr. Elger witnessed a similar appearance on April 14, 1870. (Interval 132 to 144 hours.)

Summary.—Sun's altitude 39° 50′·5 to 39° 9′·2; tint of floor 0·66 to 0·65. Streaks generally visible—the sector, east and middle arms of trident, with

the northern bifurcation of the western arm δ, the N.W. and N.E. streaks except β, which is less frequent.

Interval 156 to 144 hours.

1870, July 14.—Mr. Gledhill recorded the floor as dark =,0·66. The sector and streaks seen were dense and bright; the streak η was seen near the border; α had a condensed brightness in the middle; the south ends of the south streaks ζ and ϵ were brightest. With powers 150 and 115 the sector appeared to be condensed at the apex. On the same night (July 14) Mr. Ingall speaks of the floor being, at times of fine definition, covered with spots of light. I have registered it as very light, = 0·00; it must, however, be considered as *exceptional*, the floor being dark under a high sun. This extraordinary spottiness of the floor appears to be of the same nature as the appearances of the Mare Crisium, related in Webb's 'Celestial Objects,' third edit., pp. 82 & 83. Mr. Ingall gives the distribution of the markings as follows:—*First.* A large white cloud stretching half round the crater-floor from spot No. 14 to spot No. 3. This white cloud occupies the position of the middle and the east arms of the trident and that of the sector, with its extension to spot No. 3, the sector and the two arms of the trident being connected. It is remarkable that this cloud is entirely separated from the border; and, so far as the sector is concerned, we have a similar observation by Mr. Elger on May 13, 1870. (See Interval 132 to 144, *ante*, p. 286.) *Second.* A detached fainter cloud on the N.W. part of the floor, which occupies precisely the position of the curved streak c, with its convexity towards the border; it incloses spot No. 16. *Third.* A small detached mist on the S.W. part of the floor, which occupies the position of Gledhill's streak θ. *Fourth.* A curious brush of light adjoining the N.W. border (Webb's elbow), much brighter near the wall. The difference between Mr. Gledhill's and Mr. Ingall's observations, particularly as regards the absence of streaks near the border, except Webb's elbow, which characterizes Mr. Ingall's, is doubtless due to the difference of apertures. The elbow appears to have been seen well in both instruments.

1869, August 23.—See *ante*, p. 253.

1870, November 9.—Mr. Elger recorded the markings as faint, except the sector and γ; the latter is described as unusually bright.

1869, October 21.—Mr. Gledhill described the streaks α, β, η, and γ as seen on the 19th, but brighter; he also described the apex of the light-sector as reaching to about spot No. 3; he has, further, this remark:—"On the S.W. rim of Plato, near or at the foot of the inner slope, are three bright foci; from these the three great bright streaks on the floor proceed,—(1) a line from the uppermost, on the S. border, produced to N.E., cuts spots Nos. 1 and 3 [this must be the streak ϵ]; (2) a line from the next lower produced passes just S. of spot No. 3 [this is Gledhill's θ]; (3) a line from the lowest, towards the N.W., cuts the E. border of Plato just below or N. of II $E\psi^2$. I could not trace the streaks well which proceeded from these foci. On the same evening, with the Royal Astronomical Society's Sheepshank's telescope No. 5, aperture 2·75 inches, power 100, I observed Plato and found the floor very ill-defined, the sector the only light marking visible; it was brightest towards the S.E. border. Definition, Earth's atmosphere 'very bad, much boiling and fluttering.' The definition on the moon was very irregular; Plato was very difficult to observe, while the markings around Copernicus and Kepler were admirably seen. I determined the following tints:—the surface around Kepler $=5^c{\cdot}0$; Plato, the S.E. part of sector, $=4^c{\cdot}8$; Mare Imbrium, S. of Plato, $=4^c{\cdot}4$; Mare Imbrium, between the Mountain Chajorra and Straight chain,

$=3^{\circ}\cdot6$; Plato, the W. part of floor, $=1^{\circ}\cdot6$; Grimaldi, S. part of floor, $=0^{\circ}\cdot6$. These determinations exhibit increase of brightness with increase of numbers—Grimaldi the darkest, surface around Kepler the brighest. My estimate of the tint of the floor of Plato, on the scale adopted for comparison with the sun's altitude, was 0·66, or dark; this is about a degree brighter than the S. part of the floor of Grimaldi."

1870, September 11.—The markings, as observed by Mr. Elger, were all indistinct.

Summary.—Sun's altitude 39° 9′·2 to 37° 57′·8; tint of floor 0·65 to 0·64. Streaks generally visible—the middle arm of trident, sector, and γ the most frequent; the east arm of trident and the N.E. streaks less frequent.

Interval 144 to 132 hours.

1870, April 17.—Mr. Gledhill recorded the floor as dark, =0·66, and the N. streaks as brightest; β as bright as the sector, and γ, η seen only at the foot of the slope.

1869, May 27.—Mr. Gledhill records the sector as ill-defined below.

1871, January 8.—Mr. Gledhill described the streaks as having been well seen; one, not named, as very sharply defined, bright, narrow, and straight. This I apprehend to be α, as Mr. Gledhill generally describes it as such.

1869, December 20.—Mr. Gledhill recorded the floor as dark, =0·66. Streak seen (bright); sector a fine striking object. On the same evening Mr. Pratt recorded the markings as peculiarly indistinct, from which he considered the apparent difference of form which he observed to arise. The trident near spot No. 1 was shaded off. The greatest peculiarity shown by Mr. Pratt in his diagram is a bifurcation in the neighbourhood of streak β, or rather two streaks from spot No. 3 instead of one. Mr. Elger on the same evening showed one only, very narrow, and remarked the portion of the floor between β and η to be very dark. Mr. Elger further said, "a remarkable feature observed was the strip of light (streak γ), which during the whole evening was by far the brightest marking on the floor." This streak is not recorded by Mr. Gledhill, who noticed the sector as being the most striking object. Mr. Elger saw a part of e and Webb's elbow i, which he described as the brightest on this part of the floor.

1870, August 13.—On this evening the floor was recorded as "dark" by three observers, Mr. Pratt, Mr. Gledhill, and Mr. Neison. Mr. Pratt remarked:—"On this evening, *as well as* 1870, *Aug.* 12, the tint of the dark portions of the floor was much intensified close to the rim; it was the case *all round*, but especially so between b and ζ, between ϵ and ζ, and between β and η." Mr. Gledhill observed the streaks to be very bright; they appeared to stand out in relief. Compare with Mr. Pratt's suggestion (1870, October 17) of the light-streaks being analogous to spurs (Report, 1871, p. 95).

1870, October 11.—Mr. Elger recorded the streak η as very faint.

Summary.—Sun's altitude 37° 57′·8 to 36° 17′·5; tint of floor 0·64 to 0·62. Streaks generally visible—the sector much more frequent than the others; next in order east arm of trident, γ, β, and α. The N.W. streak and middle arm of trident less frequent, the others rarely seen.

Interval 132 to 120 hours.

1870, March 19.—Mr. Gledhill recorded the floor as dark, =0·66; he described the sector and α as very bright, the brightest on the floor.

1870, November 10.—Mr. Elger described the markings as better seen

on this evening than on any other during the lunation. Webb's elbow and c well seen.

Summary.—Sun's altitude 36° 17′·5 to 34° 11′·5; tint of floor 0·62 to 0·60. Streaks generally visible—the sector, trident, and N.E. streaks.

Interval 120 to 108 hours.

1871, January 9.—Mr. Gledhill's remarks are the same as on January 8, under interval 144 to 132 hours. See *ante*, p. 293.

1869, December 21.—Mr. Gledhill recorded the floor as dark, =0·66. Streaks *all* fairly seen, except δ and η. [I suppose by *all* Mr. Gledhill means those which he has *lately* seen; I have accordingly recorded b, a, ϵ, ζ, θ, and γ.] Mr. Gledhill mentioned none as bright except a and the sector, and they were not bright and clear as usual; a was perhaps the brightest. A bright brush of light was seen near B. & M.'s δ on the border, which appeared to merge into a and δ. A line through spots Nos. 17 and 1, produced to the N.W. border, cut the border just above or to the south of the brush, which is Webb's elbow i. The brightest portion of the border is described as that to the north of the streak a, the east end of the bright part of the border being much the brightest. A diameter at right angles to the longitudinal diameter of Plato passing through spot No 1 would cut the east and brightest extremity. Mr. Gledhill adds, " It seems a long narrow basin."

Summary.—Sun's altitude 34° 11′·5 to 31° 42′·7; tint of floor 0·60 to 0·57. Streaks generally visible—middle and eastern arm of trident, sector, γ and a; others less frequent.

Interval 108 to 96 hours.

1871, February 8.—Mr. Pratt described the streaks as ill-defined, except l, which was very fairly seen and much brighter than any part of the trident.

1870, July 16.—Mr. Gledhill recorded the floor as medium, =0·50; he described all the streaks as bright, except λ and μ, which were faint. a, β, γ, δ, ϵ, ζ were all well seen: η was seen near the border, and a had a condensed central portion; the south streaks (ζ, ϵ) were brightest at their southern ends. Mr. Gledhill does not mention the sector; but it is very probable that he saw it, by his recording *all* as bright.

1869, August 25.—Mr. Gledhill recorded the sector as "very faint" at 11 hours; at 13.30 he recorded it as "fine."

1870, September 13.—Mr. Gledhill recorded the floor as dark, =0·66. The streaks were very bright and well seen. Mr. Gledhill measured the positions of streaks ζ, ϵ, δ, and a with the sector (see Report Brit. Assoc. 1871, p. 66).

Summary.—Sun's altitude 31° 42′·7 to 28° 54′·3. Tint of floor 0·57 to 0·54. Streaks generally visible—the sector most frequent, three arms of trident; N.E. streaks much less frequent.

Interval 96 to 84 hours.

1869, December 22.—Mr. Gledhill recorded the floor as dark, =0·66. Streaks all faint; a the brightest; δ, η, and γ difficult; ϵ, ζ, and sector fairly seen, but faint. The brightest part of the inner wall was north of streak a, as well as all the west border. Shadows were already under the east border. Time 12 hours. At 12.30 Mr. Gledhill recorded the part of the inner north wall of Plato, from which the brush of light proceeded, as much less bright than the adjacent portions east and west.

1870, August 15.—Mr. Pratt recorded the floor as dark, =0·66, but

paling; the darker margins of the shaded parts of the floor were still visible as on the 12th and 13th, but not in such striking contrast.

1870, October 13.—Mr. Pratt remarked that all the objects on the floor appeared *fainter* than usual. This, which especially applies to the light-streaks, which were very well defined at their edges, is remarkable when so many spots are detected as on that evening.

Summary.—Sun's altitude 28° 54′·3 to 25° 49′·5; tint of floor 0·54 to 0·52. Streaks generally visible—the sector principally, the others but seldom, especially the N.E. streaks.

Interval 84 to 72 hours.

1869, August 26.—Mr. Gledhill recorded the sector as very faint. See *ante*, p. 254.

1870, September 14.—Mr. Gledhill recorded the floor as medium or light, =0·42; streaks faint, but well seen. Mr. Neison recorded the floor as moderately dark, =0·58, mean 0·50, or medium.

Summary.—Sun's altitude 25° 49′·5 to 22° 31′·3; tint of floor 0·52 to 0·49. Streaks generally visible—sector and eastern and middle arm of the trident.

Interval 72 to 60 hours.

1869, July 28.—Mr. Gledhill recorded the sector as faint and diffuse.

1870, August 16.—Mr. Pratt recorded the floor as medium, =0·50, and much paler than on the 13th (see *ante*, p. 293, interval 144 to 132 hours). The darker parts of the shaded portions of the floor were but just perceptible with attention.

1869, September 25.—Mr. Gledhill described the tint of the floor as "not much deeper than that of the Mare Imbrium." He appears to have seen streaks *c* ["a strong streak of light connecting the spots Nos. 16, 19, and 13, which were not seen"], κ ["a diffuse streak of light runs east from spot No. 3 parallel to that crater along spots 16, 19, 13"], and the connexion of κ with the sector ["a streak is seen from spot No. 4 to spot No. 3, as if a continuation of the sector"]. On these I have the following remark:—"*c* from the S.W. of spot No. 13 (not seen) to II E ψ^2 on the east border made out in separate streaks." The continuous direction of these streaks forming *one* white line was seen by Mr. Pratt on August 17, 23, 26, and 28 (see pp. 252–254). Mr. Gledhill described the three arms of the trident as follows:—"[ε] A rectangular luminous patch stretches from the south rim of Plato to spot No. 14, embracing it and passing on till nearly in a line with spot No 1, at which point a luminous streak [*e*] shooting from the rim and embracing spot No 22 meets it. This latter streak seemed to become a mere line as it approached the streak ε." The S.E. arm [ζ] is described as "an irregular rectangular patch of light running from the south rim to spot No. 1 nearly." It does not appear that Mr. Gledhill observed the *junction* of the three arms. The N.W. arm [*e*] is described as "very bright, the brightest, the greatest brightness being close to the rim of Plato." The central arm [ε] is described as "less bright," and the S.E. arm [ζ] as "still fainter." The apex of the sector is described as beyond spot No 4, distinctly enough extending to the streak β running from spot No. 3 to rim. The following note is appended by Mr. Gledhill:—"I could not see the limits of the three arms of the trident as they approached the centre." From his sketch Mr. Gledhill appears to have seen the streak "*o*" and its continuation α, his delineation being almost identical with Mr. Elger's of September 20. It is not at all improbable that a change had occurred in the N.W. part of the

floor, c and κ being much fainter and the western part of c obliterated, even in the larger aperture of the Halifax refractor, as compared with the seeings and drawings of Mr. Pratt in August 1869; the change consisted in the fading of κ and c and the intensification of a and "o."

For Mr. Gledhill's drawing see *ante*, p. 263.

1870, October 14.—Messrs. Gledhill and Pratt both recorded the floor as medium, =0·50. Mr. Pratt remarked that the streaks were difficult, considering the number of spots that were visible.

Summary.—Sun's altitude 22° 31'·3 to 19° 2'·0; tint of floor 0·49 to 0·45. Streak generally visible, the sector.

Interval 60 to 48 hours.

1869, August 27.—See *ante*, p. 254.

1869, October 25.—Mr. Gledhill recorded the floor as light, =0·33, the sector as "very faint, and differing but little in brightness from the floor to the east of it; its base was bounded by three craters, Nos. 26, 27, and 28, on the inner slope of Plato; its apex extended beyond spot No 4, and it cut streak β a little east of spot No. 3:" the streak γ is described as bright, sharp, and narrow.

Summary.—Sun's altitude 19° 2'·0 to 15° 23'·3; tint of floor 0·45 to 0·42; the streak β most frequent.

Interval 48 to 36 hours.

1869, December 24.—Mr. Gledhill recorded the floor as light, =0·33; the sector as large and diffuse, scarcely brighter than the adjacent floor; outline not sharp. The streaks δ, ϵ, ζ about as faint as the sector; β, η, and γ not fairly seen; all are faint. All along the north border of the pointed shadow from B. & M.'s ζ Mr. Gledhill saw a fringe of light (see Interval 24 to 36 hours, 1869, Dec. 12, *ante*, p. 275; also quotation, Elger's Observation 1871, Nov. 20, *post*, p. 299), *i. e.* the floor adjacent to the north edge of this shadow was quite bright up to the foot of the border of Plato. a appeared brighter than any other streak.

1870, August 17.—Mr. Gledhill recorded the floor as rather bright, registered at 0·40: streaks faint; a was the brightest, but it was neither dense nor broad, nor could it be said to be really bright; the others were fainter than it. The sector had ill-defined edges.

Summary.—Sun's altitude 15° 23'·3 to 11° 38'·2; tint of floor 0·42 to 0·39. Streaks generally visible—sector and eastern arm of trident, others not so frequent; all recorded as faint.

Interval 36 to 24 hours.

1870, March 23.—Mr. Gledhill recorded the floor as medium, =0·50. He described the sector and a as easily, but not well, seen; a was diffuse, and extended up to the north border [in December the brightness near the border subsided after interval 60 to 72 hours, see *ante*, p. 268]: δ, ϵ, ζ seen with some difficulty; they were much fainter than a and the sector. The shadow of B. and M.'s ζ was on the floor, and the adjacent floor to the N.W. was *very bright*, much brighter than a or the sector. The bright space was directed to spot No. 4, and it extended one third of the distance from the border to No. 4. Mr. Gledhill could not determine its shape; but it appeared to him as an intensified form of the streak η, and was the most striking object on the floor.

1870, July 19.—Mr. Gledhill recorded the floor as bright, =0·33. The streaks but little brighter than the floor; none were striking objects.

1869, August 28.—See *ante*, p. 254.

1870, November 14.—Mr. Pratt at 10 hours recorded as follows:—"Definition very bad; a large area of the floor to the S.E. shaded off delicately, as of a slightly lower level. Tint of unshaded part a little darker than the surrounding Mare, that of the shaded portion as dark again. The outline of the shaded part conforms roughly with that area of the floor adjoining the inner edges of streaks *b* and *κ*." [Mr. Pratt has furnished a sketch, dated 1870, November 15, 11.50, which I apprehend from his letter, combined with the date of his observation, should be November 14, and that the S.E. part of the floor should be S.W.; with these corrections the sketch and observations agree.] Mr. Pratt's record proceeds thus:—"These observations have much confirmed in my own mind some previous ideas, faintly shaped by former views, that the light-streaks are merely parts of the floor relatively raised and perhaps more rugged and broken (hence one cause for their contrast in tint with the rest of the floor), and that the spots are, especially several of them, raised: perhaps they are the centre points of the latest activity, which also possibly produced the streaks by raising them above the level. Was it by successive deposits of ejected material? One would have expected a lava-like deposit after reading Piazzi Smyth's 'Teneriffe.'" [The contrast of colour is a most important study, which may be greatly advanced by continuous observations of the variations in intensity of two or more neighbouring spots.] On the same evening, November 14, Mr. Gledhill recorded the floor as light, =0·33, and the streaks as very faint. Mr. Gledhill noticed that the floor was separated into a lighter and darker portion, the line of separation consisting of the west edge of the sector produced to meet the north border. The floor to the east of this line is bright, and to the west darker. [This line would be nearly in the direction of the fault in the neighbourhood of which the surface is raised, and the difference of tint is most likely produced by the obliquity of the sun's rays.] Mr. Pratt's sketch is in perfect accordance with Mr. Gledhill's observations.

1869, October 26.—Mr. Gledhill recorded the floor as bright, =0·33. The spots, except No. 1, were not readily seen; the sector and streaks were faint.

Summary.—Sun's altitude 11° 38′·2 to 7° 48′·1; tint of floor 0·39 to 0·36.

Interval 24 to 12 hours.

1869, September 27.—Mr. Gledhill recorded the floor as not so dark as the Sinus Iridum, nor so light as that of Archimedes; it is registered as light, =0·33. Mr. Gledhill described the streak *e* as a broad band of brightness, width about one third the distance from the north rim to spot No. 1, enclosing spots Nos. 13, 19, and 16; the streak *β* he described as a faint belt from spot No. 3 to the east edge of Plato. The limits of both bands were very indefinite.

Summary.—Sun's altitude 7° 48′·1 to 3° 54′·8; tint of floor 0·36 to 0·33.

Interval 12 to 0 hours.

1869, October 27.—Mr. Gledhill recorded the sector as very faint and indefinite; the streaks all very faint indeed, yet all seen at best moments. Floor registered as light, =0·33.

1870, November 15.—Mr. Gledhill recorded the floor as light, =0·33, but consisting of two parts, the eastern light and the western dark. Mr. Pratt's observations, 1869, August 28, interval 36 to 24 hours, were similar in character. See Report Brit. Assoc. 1871, p. 86.

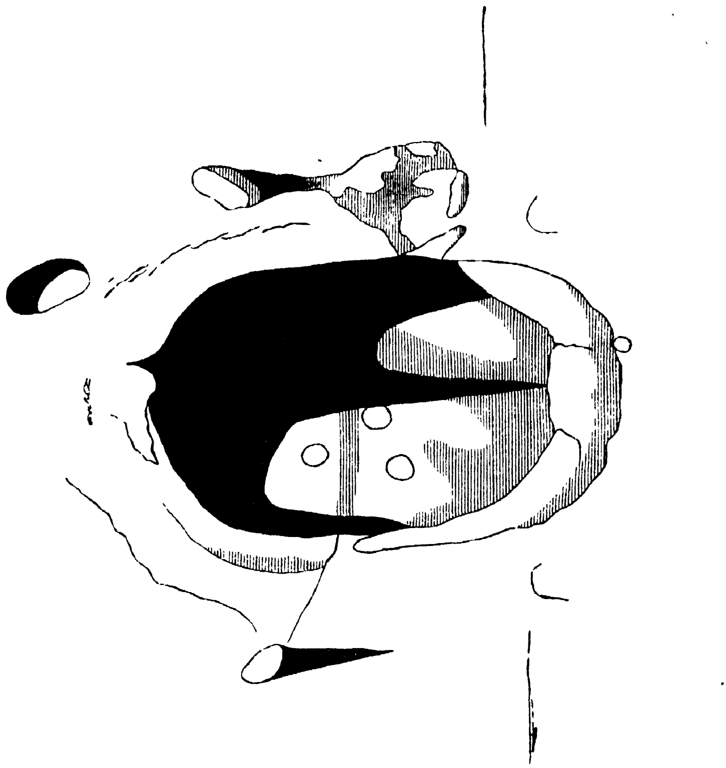
Summary.—Sun's altitude 3° 54′·8 to 0° 0′; tint of floor 0·33 to 0·30.

Interval 0 to 12 hours.

(Near the summer solstice.)

In the Report for 1871 (see Report Brit. Assoc. 1871, pp. 94, 95) a description of sunset, as observed by Mr. Pratt, is inserted. Mr. Pratt's letter was accompanied by a drawing, a copy of which is given below.

Fig. 20.



1870, Oct. 17, 11^h to 12^h. Sunset observed by Mr. Pratt.

APPENDIX.

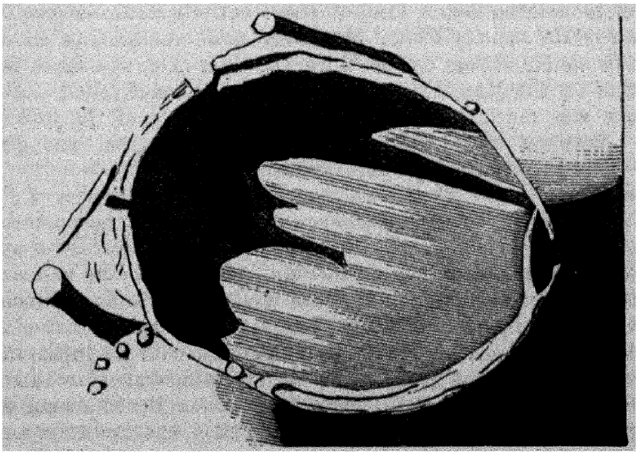
Although the epochs of the following observations are not within the period embraced in the foregoing discussion, they bear so intimately upon the results that a notice of them may not be inappropriate.

On November 20, 1871, I observed sunrise on Plato with the Royal Astronomical Society's Sheepshank's No. 5 telescope, aperture 2·75 inches, power 100. At 5.50, Greenwich mean time, I made the following record:—" The appearance of Plato, examined at intervals of a few minutes since 4.35, has been very curious to-night. I have been unable to divest myself of the impression that a kind of sparkling or agitation played *over* the dark floor deep in shadow. This appearance has latterly greatly increased, and now there are two well-marked regions (but by no means distinct streaks of sun-

light) north and south on the floor; they are parallel, and are separated by a darker region of an intensity equal to the west part of the floor, which extends over about one third of the longest diameter." At 6.0 the record runs thus:—"There is no doubt of the northern streak of sunlight existing on the floor, and traces of the southern streak are becoming apparent. Not the slightest appearance of the streak seen by Bianchini (see Report Brit. Assoc. 1871, p. 73) has been observed. 6.20. The northern and southern streaks of sunlight are both decided; their western extremities lie upon the line of fault from N.W. to S.E. The long shadow of the peak δ is now seen; it aligns with the north part of II $E\psi^2$ and the rock ζ, or rather the inlet between them and the bases of the first group of mountains of the Alps west of Plato. 6·30. The light of the northern streak is the most intense, although both are faint. 6.45. The southern streak of sunlight is greater in extent (width) than the northern, perhaps nearly double. Although definition on the moon's surface is generally good, there appears to be a want of defining power *within* Plato. Occasionally I see something approaching to well-defined shadows, but greatly inferior to what I usually see with this glass. The streaks of sunlight do not come out with that intensity which I remember to have seen them on January 10, 1870. 7.10. Sunlight on Plato increases in intensity, but the shadows are deficient in definition, and the streaks terminate on the east at some distance from the border, indicating a considerable dip of the floor, if, indeed, the sunlight be reflected from the true floor. 7.15. In best moments I see the northern edge of the shadow of the peak γ. The general character of the reflected sunlight is faint. The north edge of the shadow of γ aligns with the south part of II $E\psi^2$ and the summits of the group of mountains west of Plato, the bases of which aligned with the shadow of δ and the north part of II $E\psi^2$. The floor appears to be much darker than the site of Newton to the south."

On the same evening Mr. Elger observed and sketched Plato; his drawing, fig. 21, made at 7.30, aperture 4 inches, power 115, exhibits a feature which,

Fig. 21.



so far as I am aware, has not been observed before, viz. a number of streaks parallel to the longest diameter of Plato, which Mr. Elger described as "very

striking." At a still later period Mr. Neison observed Plato from 8.5 to 8.35. He described the floor as "very dark," and gave two gradations of shadow, that in the south-west being marked "dark shadow," while the portion beyond, towards the east, he marked "shadow." This portion is drawn as extending nearly to spot No. 17, bisecting spot No. 1, and passing a little west of spot No. 16. On comparing the drawing with Mr. Elger's at an earlier epoch, it would appear that Mr. Neison's "shadow" was in some way connected with the streakiness observed by Mr. Elger; for by 8.35 the true shadow must have retreated to about the position given by Mr. Neison for his "dark shadow." The outline also of Mr. Neison's "shadow" is not in accordance with the peaks on the west border. Mr. Neison further described the northern light-streak and sector as very distinct and of a pearl-grey colour, and spots Nos. 3 and 17 of a pale grey colour, which he saw distinctly. Spots Nos. 16 and 25 are described as "faint." "Although," says Mr. Neison, "this is extremely early, the spots were extremely plain." Mr. Elger's remark is as follows:—"Sunrise finely seen; shadows of peaks γ, δ, ϵ very sharply defined; no spots observed."

The *darkness* of the floor is alike recorded by myself and Mr. Neison; and Mr. Elger's drawing testifies equally to it, especially on the north-east portion. It is this darkness, so unusual at sunrise, combined with the difficulty of making out the streaks and shadows on my part, and the observation by Mr. Elger of the peculiar streakiness, so unlike the ordinary light-streaks on the floor, that lead me to suspect that on the 20th of November, 1871, between 4.35 and 7.40 G. M. T., the interior of Plato was in an abnormal state.

While the above-recorded observations were in progress, and the difficulty of observing the interior of Plato from 5.50 to 7.15 was very great, Mr. Pratt observed a very remarkable phenomenon on the Mare Frigoris, which he described as one of the most singular and striking of all the *local observations* he had witnessed. The following is an extract from his observing-book:—"5.30. On a *general* survey of Plato and wide neighbourhood, the very peculiar aspect of the Mare Frigoris attracts attention. The appearance can be compared to nothing but a kind of haze, entirely local, *hanging round the N.W. foot of the slope of Plato*. It is the more conspicuous as nothing of the kind is visible either on the Mare Imbrium or on the Mare Serenitatis. The objects on the Mare Frigoris were indistinct, as if veiled. At 6.30 the appearance was much modified. At 7.30 very little of the veiling was to be seen. Between other observations frequent attention was given to it until 9.0, but no return of the phenomenon appeared."

The contemporaneity of my own observations of the interior of Plato with those of Mr. Pratt of an immediate contiguous locality, is conclusive of the connexion between the *abnormal* condition of Plato and the *veiled* appearance of the N.W. slope, extending to the Mare Frigoris. On other occasions Mr. Pratt has described the appearance of the floor of Plato as if seen through a veil of thin white polarized clouds, such as appear in our own atmosphere. Phenomena of this kind are strikingly in contrast with an appearance which I witnessed on the same evening and at the same time,—it was the sharp and well-defined character of the broad band of roughened ground extending from the Apennines to the region of Ukert, Pallas, and Bode.

Such observations as the foregoing remind one strongly of similar observations recorded on numerous occasions by Schröter, which are said by the greatest Selenographer of the present century to have been *proved* to have been *illusions*. It is a remarkable fact, and one well worthy of deep con-

sideration, that whenever *close attention* is given to the moon's surface something of the kind is sure to crop up; nor is it confined to eye observations alone; photography tells the same tale. In the letterpress to the fourth area of the Lunar Map I have given instances of differences between photograms of various dates; and in drawing up my monogram of Hipparchus, I compared every object in every available photogram. It is much to be regretted that a means of detecting differences, if not changes on the moon's surface, should be so little utilized, for I have not met with any published results of the comparison of lunar photograms except my own, as specified above; and we know that numerous negatives must be in existence. We can hardly conceive it possible that *illusion* can enter as an element here; apparent differences may result from flaws either in the originals or in printing, but these are capable of being eliminated: and, again, on photograms we have whatever differences may present themselves *under the eye*; whereas in those observed with the telescope we have the records only to depend upon, and these records will be more or less convincing according to the impression made by the phenomena on the mind at the time. As illustrative of this I quote Mr. Pratt's remarks in connexion with the phenomena of November 20, 1871:—"Whether or no Lunar Meteorology ever becomes an *accepted* fact, I shall always retain a strong belief that this observation was one of the earliest and most complete records I know of, from the greatest intensity of the mist, or whatever it was that obscured the region, until its entire dissipation by the rays of the rising sun." With this Mr. Pratt contrasts an observation of the Mare Frigoris on December 27, 1871, as follows:—"Definition of objects on the Mare Frigoris fully as good as on any part of the border of Plato, in marked distinction to the observation of November 20, 1871."

One of the results of my late discussion of observations of the floor of Plato is, that certain peculiar phenomena, consisting of variations of the brightness of the N.W. floor and in the forms of the streaks thereabout, have been noticed during the greater part of two years by two or more independent observers. On the 22nd of December, 1871, Mr. Pratt noticed "a marked haziness over the north-west part of the floor of Plato, an instance of very limited mistiness." Still, comparison with other portions of the floor rendered it to Mr. Pratt's mind a no less certain instance than the former one of the Mare Frigoris; for to one who has so constantly worked at the floor, even limited phenomena would be as apparent as those of wider range to the general observer.

Now what are we to say to *illusion*? Here are independent observers during a period of many months testifying to the existence of the same phenomena; and not only so (for their testimony would have been weak had we merely taken a disjointed remark here or there, or had one observer only, as in the case of Schröter, recorded these seeings), but we have had the observations carefully examined and arranged under certain heads, the evidence has been sifted, and we think that an impartial verdict would negative illusion, and declare for some active element producing the phenomena observed. What that element is becomes a most interesting question. So far as we have been able to make out, the most active agency that has modified the moon's surface is volcanic. Have the appearances to which allusion has been made any connexion with a continuance of this agency?

Report on the Mollusca of Europe compared with those of Eastern North America. By J. Gwyn Jeffreys, *F.R.S.*

[A communication ordered by the General Committee to be printed *in extenso.*]

After mentioning that he had dredged last autumn on the coast of New England in a steamer provided by the Government of the United States, and that he had inspected all the principal collections of Mollusca made in Eastern North America, the author compared the Mollusca of Europe with those of Massachusetts. He estimated the former to contain about 1000 species (viz. 200 land and freshwater, and 800 marine), and the latter to contain about 400 species (viz. 110 land and freshwater, and 290 marine); and he took Mr. Binney's edition of the late Professor Gould's 'Report on the Invertebrata of Massachusetts,' published in 1870, as the standard of comparison. That work gives 401 species, of which Mr. Jeffreys considered 41 to be varieties and the young of other species, leaving 360 apparently distinct species. About 40 species may be added to this number in consequence of the recent researches of Professor Verrill and Mr. Whiteaves on the coast of New England and in the Gulf of St. Lawrence. Mr. Jeffreys identified 173 out of the 360 Massachusetts species as European, viz. land and freshwater 39 (out of 110), and marine 134 (out of 250), the proportion in the former case being 28 per cent., and in the latter nearly 54 per cent.; and he produced a tabulated list of the species in support of his statement. He proposed to account for the distribution of the North-American Mollusca thus identified, by showing that the land and freshwater species had probably migrated from Europe to Canada through Northern Asia, and that most of the marine species must have been transported from the Arctic seas by Davis's-Strait current southwards to Cape Cod, and the remainder from the Mediterranean and western coasts of the Atlantic by the Gulf-stream in a northerly direction. He renewed his objection to the term "representative species." The author concluded by expressing his gratitude for the kind hospitality and attention which he received from naturalists during his visit to North America last year.

Mollusca of Eastern North America, according to Binney's edition of Gould's 'Invertebrata of Massachusetts.'

Page.	Name of Species.	North or South of Cape Cod.	European.	Synonyms and Remarks.
28	Teredo navalis, *Linné*	N	E	Wood's Hole, Mass. (J. G. J.).
29	—— Norvagica, *Spengler* ...	N	E	
30	—— megotara, *Hanley*	N	E	
31	—— Thompsonii, *Tryon*......	S		
32	—— dilatata, *Stimpson*	N	......	*T. megotara*, variety.
33	—— chlorotica, *Gould* (1870).	N	E	*T. pedicellata*, Quatrefages (1849), var.
34	Xylotrya fimbriata, *Jeffreys* ..	S		
36	Pholas costata, *L.*...............	S		
38	—— truncata, *Say*	S		
39	Zirfæa crispata, *L.*	N	E	Genus *Pholas*.
40	Solen ensis, *L.*	N	E	
43	Solecurtus gibbus, *Sp.*	S		
44	—— divisus, *Sp.*	S		

Page.	Name of Species.	North or South of Cape Cod.	European.	Synonyms and Remarks.
46	Machæra squama, *Blainville* .	N	......	G. *Siliqua.*
47	—— costata, *Say*	N	......	G. *Siliqua.*
48	Solemya velum, *Say* (1822)...	N	......	*S. togata*, young.
50	—— borealis, *Totten* (1834) ..	N	E	*S. togata*, Poli (1791).
51	Panopæa arctica, *Lamarck* (1818)	N	E	*Saxicava Norvegica*, sp. (1793).
53	Glycymeris siliqua, *Chemnitz* .	N	E	G. *Cyrtodaria.*
55	Mya arenaria, *L.*	N	E	
58	—— truncata, *L.*	N	E	
60	Corbula contracta, *Say*.........	S		
61	Neæra pellucida, *St.*	N	E	
62	Pandora trilineata, *Say*	N		
64	Lyonsia hyalina, *Conrad*	N	......	Allied to *L. Norvegica.*
65	—— arenosa, *Moller*	N	E	
66	Anatina papyracea, *Say*	N		
68	Cochlodesma Leanum, *Conr.* .	N	......	Allied to *Thracia prætenuis*, which is European.
69	Thracia Conradi, *Couthouy* (1838)........................	N	......	*T. inflata*, J. Sowerby (1845).
71	—— myopsis (*Beck*), *Moll* (1842).......	N	E	*T. truncata*, Brown (1827).
72	—— truncata, *Mighels & Adams* (1842).	N	E	Not *T. truncata*, Br. *T. septentrionalis*, Jeffr. MS.
73	Mactra solidissima, *Ch.*	N	......	Lovén received a single valve from Finmark.
75	—— ovalis, *Gould*	N	......	*M. solidissima*, var.
77	—— lateralis, *Say*	N	......	Allied to *M. subtruncata*, which [is European.
79	Cumingia tellinoides, *Conr.*...	S		
80	Ceronia arctata, *Conr.*	N	......	*Mesodesma deauratum*, var.
81	—— deaurata, *Turton*	N	......	G. *Mesodesma.*
83	Kellia planulata, *St.*...........	N	......	G. *Lasæa.*
83	—— suborbicularis, *Montagu.*	N	E	
85	Turtonia minuta, *Fabricius*...	N	E	G. *Cyamium.*
86	Montacuta elevata, *St.*.........	N	E	
87	Saxicava rugosa, *Pennant*.....	N	E	Linné instead of Pennant.
89	—— arctica, *L.*..	N	.. ...	*S. rugosa*, var.
90	Petricola pholadiformis, *Lam.*	N	......	Valentia, Ireland; a fragment.
92	—— dactylus, *Say*	N	......	*P. pholadiformis*, var.
93	Macoma fusca, *Say* (1826) ..	N	E	*Tellina Balthica*, L. (1766).
95	—— proxima, *Gray* (1839)...	N	E	*T. calcaria*, Ch. (1782).
96	Tellina tenta, *Say*......... ...	S		
97	—— tenera, *Say*	N	......	Allied to *T. tenuis.*
98	Lucina filosa, *St.* (1851)	N	E	*L. borealis*, L. (1766).
99	—— dentata, *Wood*	S		
100	Cryptodon Gouldii, *Philippi* (1845).	N	E	*Axinus flexuosus*, Mont., var. (1803).
101	Sphærium simile, *Say* (1816).	N	......	*S. striatinum*, Lam. (1818).
103	—— partumeium, *Say* (1822)	N	E	*S. lacustre*, Muller (1774).
104	—— rhomboideum, *Say*	N	......	Allied to *S. corneum*, which is European.
105	—— Vermontanum, *Prime* (1861).	N	E	*S. pisidioides*, Gray (1856). Perhaps introduced into England.
106	—— truncatum, *Linsley*	N	......	*S. lacustre*, var.
107	—— tenue, *Prime*	N		
107	—— securis, *Prime*	N	......	*S. lacustre*, var. *Rykholtii.*

Page.	Name of Species.	North or South of Cape Cod.	European.	Synonyms and Remarks.
108	Sphærium occidentale, *Prime*	N		
109	Pisidium dubium, *Say* (1816)	N	E	*P. amnicum*, Mull. (1774).
110	—— Adamsii, *Prime* (1851)...	N	E	*P. fontinale*, Draparnaud (1805).
110	—— compressum, *Prime*	N		
112	—— æquilaterale, *Prime*	N	......	Allied to *P. nitidum*, which is European.
113	—— ferrugineum, *Prime*	N	......	*P. pusillum*, var. *obtusale*.
113	—— abditum, *Haldeman* (1841)	N	E	*P. pusillum*, Gmelin (1788).
115	—— variabile, *Prime*	N		
116	—— ventricosum, *Prime*	N	......	Possibly some of these North-American species may be reduced in number.
117	Astarte castanea, *Say*	N	......	Perhaps a variety of *A. borealis*, Ch.
119	—— sulcata, *Da Costa*	N	E	Including *A. undata*, Gould = *A. Omalii*, J. Sow.
121	—— semisulcata, *Leach* (1817)	N	E	*A. borealis*, Ch. (1784), var.
123	—— quadrans, *Gould*	N	.....	*A. castanea*, var. *nana*.
124	—— elliptica, *Hanley*	N	......	*A. sulcata*, var.
125	—— Banksii, *Leach* (1817)...	N	E	*A. compressa*, Mont. (1803), var.
126	—— crebricostata, *Forbes* (1847)	N	E	*A. depressa*, Br. (1827).
127	—— Portlandica, *Mighels*	N	......	*A. compressa*, var.
128	Gouldia mactracea, *Linsley* ...	N	......	G. *Crassatella*.
129	Cyprina Islandica, *L.*	N	E	
131	Cytherea convexa, *Say*	N	......	G. *Venus*.
133	Venus mercenaria, *L.*	N		
135	—— notata, *Say*	N	.. ...	*V. mercenaria*, var.
136	Tapes fluctuosa, *Gould*	N	E	G. *Venus*.
137	Gemma gemma, *Totten*	N	.. ...	*V. mercenaria*, young.
138	—— Manhattensis, *Prime* ...	S		
139	Cardium Islandicum, *L.*	N	E	
141	—— elegantulum (*Beck*), *Moll.*	N	E	
143	Liocardium Mortoni, *Conr.*...	N	.....	G. *Cardium*.
144	Aphrodita Grœnlandica, *Ch.* .	N	E	
146	Cardita borealis, *Conr.* (1836)	N	E	*C. sulcata*, Bruguière (1792), var.
147	Arca pexata, *Say*	S		
148	—— transversa, *Say*	N	.. ..	*A. pexata*, var.
149	Nucula tenuis, *Mont.*	N	E	
150	—— proxima, *Say*	N		
152	—— expansa, *Reeve*	N	......	*N. tenuis*, var.
153	—— delphinodonta, *Migh.* ...	N	E	
154	Yoldia limatula, *Say* (1831)..	N	E	*Y. arctica*, Sars. G. *Leda*.
155	—— obesa, *St.*	N	......	Allied to *Leda lucida*, which is European.
156	—— siliqua, *Reeve* (1855) ..	N	E	*L. arctica*, Gray (1819).
157	—— thraciæformis, *Storer* ...	N	E	G. *Leda*.
159	—— sapotilla. *Gould* (1841) .	N	E	*L. hyperborea*, Lov. (1846).
160	—— myalis, *Couth.*	N	......	G. *Leda*.
161	Leda tenuisulcata, *Couth.* (1838)	N	E	*L. pernula*, Müll. (1770), var.
163	—— Jacksonii, *Gould*	N	.. ...	*L. pernula*, var.

Page.	Name of Species.	North or South of Cape Cod.	European.	Synonyms and Remarks.
164	Leda minuta, *Fabr.*	N	E	Mull. instead of Fabr.
165	—— caudata, *Donovan*	N	.....	*L. minuta*, var.
167	Unio complanatus, *Solander*	N		
169	—— nasutus, *Say*	N		
170	—— radiatus, *Gm.*	S		
172	—— cariosus, *Say*	S		
173	—— ochraceus, *Say*	S	......	Perhaps *U. cariosus*, var
174	Margaritana arcuata, *Barnes* (1823)	N	E	*Unio margaritifer*, L. (1766).
176	—— undulata, *Say*	S	.....	G. *Unio.*
177	—— marginata, *Gould*	S	.....	G. *Unio.*
178	Anodon fluviatilis, *Lea*	S	......	Dillwyn (1817) instead of Lea. *Anodonta cygnea*, L. (1766).
180	—— implicata, *Say*	N	.. ..	G. *Anodonta*. *A. cygnea*, var.
182	—— undulata, *Say*	S	.. .	G. *Anodonta.*
183	Mytilus edulis, *L*	N	E	
186	Modiola modiolus, *L.*	N	E	G. *Mytilus.*
188	—— plicatula, *Lam.*	N	.. ..	G. *Mytilus.*
190	Modiolaria nigra, *Gray*	N	E	
192	—— discors, *L.*	N	E	
193	—— corrugata, *St.*	N	E	
194	Crenella glandula, *Tott.*	N		
195	—— pectinula, *Gould* (1841).	N	E	*C. faba*, Fabr. (1780).
196	Pecten tenuicostatus, *Migh. & Ad.*	N		
198	—— Islandicus, *Mull.*	N	E	
199	—— irradians, *Lam.*	N		
200	—— fuscus, *Linsl.*	N	.... .	*P. irradians*, young.
202	Ostrea Virginiana, *Lister*	N		
203	—— borealis, *Lam.*	S	.. .	*O. Virginiana*, var.
204	Anomia ephippium, *L.*	N	E	
204	—— aculeata, *Gm.*	N		*A. ephippium*, var.
205	—— electrica, *L.*	N	....	*A. ephippium*, var.
206	—— squamula, *L.*	N	.....	*A. ephippium*, young
208	Terebratulina septentrionalis, *Couth.* (1839)	N	E	*Terebratula caput-serpentis*, L. (1764), var.
210	Rhynchonella psittacea, *Gm.*	N	E	
211	Waldheimia cranium, *Gm.*	N	E	Mull., instead of Gm. G. *Terebratula*
213	Philine sinuata, *St.*	N	......	Allied to *P. nitida*, which is European.
213	—— quadrata, *S. Wood.*	N	E	
214	—— lineolata, *Couth.* (1839)	N	E	*P. lima*, Br. (1827).
215	Scaphander puncto-striatus, *Migh. & Ad.* (1842)	N	E	*S. librarius*, Lov. (1846).
216	Diaphana hiemalis. *Couth.* (1839)	N	E	*Utriculus globosus*, Lov (1846).
216	—— debilis, *Gould* (1840)	N	E	*Utriculus hyalinus*, Turt. (1834).
217	Utriculus Gouldii, *Couth.* (1839)	N	E	*U. turritus*, Moll. (1842).
218	—— pertenuis, *Migh.*	N	......	*U. Gouldii*, young.
219	—— canaliculatus, *Say*	S		
220	Cylichna alba, *Br.*	N	E	
221	—— oryza, *Tott.* (1835)	N	E	*Bulla utriculus*, Brocchi (1814).

Page.	Name of Species.	North or South of Cape Cod.	European.	Synonyms and Remarks.
222	Bulla incincta, *Migh.*	N		
222	—— solitaria, *Say*	S		
223	—— occulta, *Migh. & Ad.* (1842)	N	E	*Cylichna striata*, Br. (1827).
224	Tornatella puncto-striata, *Ad.*	S	......	Perhaps *Actæon pusillus.* G. *Actæon.*
226	Polycera Lessonii, *D'Orbigny.*	N	E	
228	Doris bilamellata, *L.*	N	E	
229	—— tenella, *Agassiz*	N	......	Perhaps *D. inconspicua*, which is European.
229	—— pallida, *Ag.* (1870)	N	E	*D. aspera*, Alder & Hancock (1842).
230	—— diademata, *Ag.* (1870)..	N	E	*D. tuberculata*, Cuvier (1802).
231	—— planulata, *St.* (1853) ..	N	E	*D. repanda*, A. & H. (1842).
232	—— grisea, *St.*	N	......	"Very closely allied to *D. inconspicua.*"
233	Ancula sulphurea, *St.*	N	......	"Very like to *Ancula cristata*," which is European.
234	Dendronotus arborescens, *Mull.*	N	E	
236	Doto coronata, *Gm.*	N	E	
238	Æolis papillosa, *L.*	N	E	
240	—— salmonacea, *De Kay* (1843)	N	......	*Eolis bodoensis*, Möll. (1842).
241	—— Bostoniensis, *Couth.*......	N	......	"Approaching closely *E. coronata* of Forbes," which is European.
242	—— rufibranchialis, *Johnston.*	N	E	
243	—— pilata, *Gould*	N		
245	—— stellata, *St.*	N		
246	—— purpurea, *St.*	N		
246	—— picta, *A. & H.*	N	E	
247	—— diversa, *Couth.*	N		
248	—— despecta, *Johnst.*	N	E	
249	—— gymnota, *De Kay*........	N	......	"Nearly allied to *E. concinna*," which is European.
250	Calliopæa (?) fuscata, *Gould*...	N		
251	Embletonia fuscata, *Gould* ...	N		
252	—— remigata, *Gould*	N		
253	Hermæa cruciata, *Alex. Ag.*...	S		
254	Alderia Harvardiensis, *Ag* ...	N		
255	Elysia chlorotica, *Ag.*	N		
256	Placobranchus catulus, *Ag.* ...	N		
258	Limapontia zonata, *St.*........	N		
258	Chiton apiculatus, *Say*.......	S		
259	—— cinereus, *L.*	S	E	*C. marginatus*, not *C. cinereus.* A single specimen only; questionable.
260	—— ruber, *Lowe*	N	E	
261	—— marmoreus, *Fabr.*	N	E	
263	—— albus, *Mont.*	N	E	L., not Mont.
263	—— mendicarius, *Migh. & Ad.* (1842)	N	E	*C. Hanleyi* (Bean), Thorpe (1844).
264	Amicula Emersonii, *Couth.* ...	N		
266	Dentalium dentale, *L.*	N	......	*D. striolatum*, var.

Page.	Name of Species.	North or South of Cape Cod.	European.	Synonyms and Remarks.
266	Entalis striolata, *St.* (1851)..	N	E	*Dentalium abyssorum*, Sars (1858), var.
267	Tectura testudinalis, *Mull.* ..	N	E	
269	—— alveus, *Conr.*..............	N	. ..	*T. testudinalis*, var.
270	Lepeta cæca, *Mull.*	N	E	
271	Crepidula fornicata, *L.*........	N	E	
272	—— plana, *Say*	N	......	*C. fornicata*, var.
273	—— convexa, *Say*	N		
274	—— glauca, *Say*	N	......	*C. fornicata*, var.
275	Crucibulum striatum, *Say* ..	N		
276	Cemoria Noachina, *L.*	N	E	G. *Puncturella*.
277	Ianthina fragilis, *Deshayes* ..	N	E	Lam., not Desh. Specific name changed to *communis* (1822).
278	Adeorbis costulata, *Moll.*.....	N	E	G. *Molleria*.
279	Margarita cinerea, *Couth.* . .	N	E	G. *Trochus*.
280	——undulata, *Sowerby* (1838),	N	E	*Trochus Grœnlandicus*, Ch. (1781).
281	—— helicina, *Fabr.*............	N	E	G. *Trochus*.
282	—— argentata, *Gould* (1841)	N	E	*Trochus glaucus*, Möll. (1842).
283	—— obscura, *Couth.*	N	E	G. *Trochus*.
284	—— acuminata, *Migh. & Ad.*..	N	......	*Trochus varicosus*, young.
285	—— varicosa, *Migh. & Ad.* (1842)	N	E	*M. elegantissima* (Bean), S. Wood (1848). G. *Trochus*.
286	Trochus occidentalis, *Migh. & Ad.*	N	E	
286	Valvata tricarinata, *Say* (1817)	N	E	*V. piscinalis*, Mull. (1774), var.
288	—— pupoidea, *Gould*	N		
289	Melantho decisa, *Say*	N		
292	Amnicola pallida, *Haldeman* .	N	.. ..	G. *Hydrobia*.
293	—— limosa, *Say*	N	.. ...	G. *Hydrobia*.
294	—— granum, *Say*..	S	......	G. *Hydrobia*.
295	Pomatiopsis lapidaria, *Say* ..	S		
296	Skenea planorbis, *Fabr.*	N	E	
297	Rissoella? eburnea, *St.*...... ..	N	......	G. *Rissoa*.
297	—— sulcosa, *Migh.*	N	......	G. *Rissoa*. One specimen only.
298	Rissoa minuta, *Tott.* (1834)...	N	E	*Hydrobia ventrosa*, Mont. (1803), var.
299	—— latior, *Migh. & Ad.*	N		
299	—— aculeus, *Gould* (1841)..	N	E	*R. striata*, J. Adams (1795).
300	—— multilineata, *St.*	N	......	*R. striata*, var.
301	—— Mighelsi, *St.*..............	N		
301	—— exarata, *St.*	N		
301	—— carinata, *Migh. & Ad.*..	N		
302	Lacuna vincta, *Mont.* (1803).	N	E	*L. divaricata*, Fabr. (1780).
303	—— neritoidea, *Gould* (1840)	N	E	*L. pallidula*, Turt. (1827), var.
304	Littorina rudis, *Don.*	N	E	Maton, instead of Don.
306	—— tenebrosa, *Mont.*	N	E	*L. rudis*, var.
308	—— litorea, *L.*........	N	E	
309	—— palliata, *Say* (1822) ...	N	E	*L. obtusata*, L. (1766), var. = *L. limata*, Low. (1846).
311	—— irrorata, *Say*..............	S		
311	Scalaria Nov-angliæ, *Couth.*...	N	......	*S. multistriata*, var.
312	—— lineata, *Say*	S		
313	—— multistriata, *Say*........	S		
314	—— Grœnlandica, *Ch.*.........	N	E	

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315	Cæcum pulchellum, *St.*	S		
316	Vermetus radicula, *St.*.........	S		
317	Turritella erosa, *Couth.* (1839).........................	N	E	*T. polaris*, Möll. (1842).
318	—— reticulata, *Migh. & Ad.* (1842).........................	N	E	*T. lactea*, Moll. (1842).
319	—— acicula, *St.*	N		
320	Aporrhais occidentalis, *Beck.*.	N		
321	Bittium nigrum, *Tott.*.........	S	......	G. *Cerithium.*
322	—— Greenii, *Ad.* (1839)	N	E	*Cerithiopsis tubercularis*, Mont. [(1803).
323	Triforis nigrocinctus, *Ad.* ...	S		
325	Odostomia producta, *Ad.*......	S		
325	—— fusca, *Ad.*	S		
327	—— dealbata, *St.*..............	N		
327	—— modesta, *St.*...............	N		
327	—— bisuturalis, *Say*	N		
328	—— trifida, *Tott.*..............	S	......	*O. impressa*, var.
329	—— seminuda, *Ad.*	N		
330	—— impressa, *Say* (1822) ...	S	......	*O. cœlata*, Cailliaud (1865).
331	Turbonilla interrupta, *Tott.* (1834).	N	E	*Melania rufa*, Ph. (1836), var. G. *Odostomia.*
331	—— nivea, *St.*	N	......	Perhaps *Turbo lacteus*, L. G. [*Odostomia.*
332	Eulima oleacea, *Kurtz & St.*.	S		
333	Menestho albula, *Moll.*........	N	......	Apparently not this species, which is European.
334	Velutina haliotoidea, *Fabr.* (1780).........................	N	E	*V. lævigata*, Pennant (1777).
335	—— zonata, *Gould* (1841) ...	N	E	*V. undata*, Brown (1827).
337	Lamellaria perspicua, *L.*	N	E	
338	Lunatia heros, *Say* (1822) ..	N	......	*Natica catenoides*, S. Wood (1848).
340	—— triseriata, *Say*	N	......	*Natica heros*, young.
341	—— Grœnlandica, *Moll.*......	N	E	Beck, *fide* Moll. G. *Natica.*
342	Natica clausa, *Broderip & Sow.* (1829).........................	N	E	*N. affinis*, Gm. (1790).
344	—— pusilla, *Say*	S		
344	Mamma? immaculata, *Tott.*..	N	......	G. *Natica.*
345	Neverita duplicata, *Say*	S	......	G. *Natica.*
347	Bulbus flavus, *Gould* (1840) ..	N	E	*Natica Smithii*, Brown (1839), =*N. aperta*, Lov. (1846).
348	Amauropsis helicoides, *Johnst.* (1835)......................	N	E	*Natica Islandica*, Gm. (1790).
349	Pleurotoma bicarinata, *Couth.*	N	E	
350	—— plicata, *Ad.* (1842)	N	E	*P. declivis*, Lov. (1846).
351	Bela turricula, *Mont.*	N	E	G. *Pleurotoma.*
352	—— harpularia, *Couth.*	N	E	G. *Pleurotoma.*
353	—— violacea, *Migh. & Ad.* (1842).........................	N	E	*Defrancia Beckii*, Moll. (1842). G. *Pleurotoma.*
354	—— decussata, *Couth.* (1841).	N	E	*Pleurotoma Trevelyana*, Turt. (1834).
355	—— cancellata, *Migh. & Ad.* (1842).........................	N	E	*Defrancia Pingelii*, Möll. (1842). G. *Pleurotoma.*
355	—— pleurotomaria, *Couth.* (1839).	N	E	*Buccinum pyramidale*, Ström (179—). G. *Pleurotoma.*

Page.	Name of Species.	North or South of Cape Cod.	European.	Synonyms and Remarks.
356	Columbella avara, *Say*	S		
357	—— rosacea, *Gould* (1840)	N	E	*C. Holbolli* (Beck), Moll. (1842).
358	—— dissimilis, *St.*	N		
359	—— lunata, *Say*	S		
360	Purpura lapillus	N	E	
362	Nassa obsoleta, *Say*	N	......	Subgenus *Paranassa*.
364	—— trivittata, *Say* (1822)	N	......	*N. propinqua*, J. Sow. (1824).
365	—— vibex, *Say*	S		
366	Buccinum undatum, *L.*	N	E	
368	—— ciliatum, *Fabr.*	N	E	Not that species, but *B. undulatum*, Moll.
369	—— Donovani, *Gray* (1839)	N	E	*B. glaciale*, L. (1766).
370	—— cinereum, *Say*	N	......	G. *Urosalpinx*, allied to *Purpura*.
371	Fusus Islandicus, *Gm.*	N	......	Not that species, but *F. curtus*, Jeffr.
372	—— pygmæus, *St.*	N	.....	Not *Buccinum Sabinii* or *Fusus Sabini*, Gray.
373	—— ventricosus, *Gray*	N		
374	—— tornatus, *Gould* (1840)	N	E	*F. despectus*, L. (1766).
375	—— decemcostatus, *Say*	N		
377	Trophon clathratus, *L.*	N	E	Not that species, but *T. truncatus*, Str.
378	—— scalariformis, *Gould* (1840)	N	E	*T. clathratus*, L (1766).
379	—— muricatus, *Mont.*	N	E	Doubtful as American.
380	Busycon canaliculatum, *L.*	S		
383	—— carica, *Gm.*	S		
385	Fasciolaria ligata, *Migh. & Ad.*	N		
386	Ranella caudata, *Say*	S		
387	Cerithiopsis Emersonii, *Ad.*	S	.....	G. *Cerithium*, not *Cerithiopsis*.
389	—— terebralis, *Ad.* (1841)	S	E	*C. trilineata*, Ph (1836).
390	Trichotropis borealis, *Sow.*	N	E	Broderip and Sowerby's species.
391	Admete viridula, *Fabr.*	N	E	
394	Vitrina limpida, *Gould* (1850)	N	E	*V. pellucida*, Mull. (1774).
395	Hyalina cellaria, *Mull.*	N	E	G *Zonites*.
396	—— arborea, *Say*	N	......	Closely allied to *Z. excavatus*, but umbilicus much less open.
397	—— electrina, *Gould* (1841)	N	E	*Zonites radiatulus*, Alder (1830), var. *alba*.
398	—— indentata, *Say*	N		
399	—— minuscula, *Binney*	N		
400	—— Binneyana, *Morse*	S		
401	—— milium, *Morse*	N		
401	—— ferrea, *Morse*	N		
402	—— chersina, *Say* (1821)	N	E	*Zonites fulvus*, Mull. (1774).
403	—— minutissima, *Lea* (1841)	N	E	*Helix pygmæa*, Drap. (1805).
404	—— multidentata, *Binney*	N		
404	—— lineata, *Say*	N		
406	Macrocyclis concava, *Say*	N		
407	Limax maximus, *L.*	N	E	
408	—— agrestis, *L.*	N	E	
409	—— campestris, *Binney* (1841)	N	E	*L. lævis*, Mull. (1774).

Page.	Name of Species.	North or South of Cape Cod.	European.	Synonyms and Remarks.
410	Limax flavus, *L.*	N	E	
412	Helix alternata, *Say*	N		
413	—— striatella, *Anthony*	N		
415	—— asteriscus, *Morse*	N		
415	—— labyrinthica, *Say*	N		
417	—— hirsuta, *Say*	N		
418	—— monodon, *Rackett*	N		
420	—— palliata, *Say*	N		
422	—— tridentata, *Say*	N		
423	—— albolabris, *Say*	N		
424	—— dentifera, *Binn.*	N		
425	—— thyroides, *Say*	N		
426	—— Sayii, *Binn.*	N		
427	—— ? harpa, *Say*	N	E	Sweden.
428	—— pulchella, *Müll.*	N	E	
429	—— hortensis, *Müll.* (1774)	N	E	*H. nemoralis*, L. (1766), var.
431	Cionella subcylindrica, *L.*	N	E	Perhaps that species, but described as inhabiting fresh water. *Cochlicopa lubrica*, Müll.
433	Pupa muscorum, *L.*	N	E	Linné's species is unascertainable. *P. marginata*, Drap.
433	—— Hoppii, *Möll.*	N		
434	—— pentodon, *Say*	N		
435	—— decora, *Gould*	N		
436	—— fallax, *Say*	S		
437	—— armifera, *Say*	N		
438	—— contracta, *Say*	N		
439	—— rupicola, *Say*	N		
439	—— corticaria, *Say*	N		
440	Vertigo Gouldii, *Binn.* (1843)	N	E	*V. alpestris*, Ald. (1830).
441	—— milium, *Gould*	N		
442	—— Bollesiana, *Morse* (1865)	N	E	*V. pygmæa*, Drap. (1801).
442	—— ovata, *Say* (1822)	N	E	*V. antivertigo*, Drap. (1801).
443	—— ventricosa, *Morse* (1865)	N	E	*V. Moulinsiana*, Dupuy (1843).
444	—— simplex, *Gould* (1840)	N	E	*V. edentula*, Drap. (1805).
445	Succinea ovalis, *Gould* (1841)	N	E	*S. elegans*, Risso (1826).
446	—— avara, *Say*	N	......	Allied to *S. putris*, var. *ochracea*.
447	—— obliqua, *Say* (1824)	N	E	*S. putris*, L. (1766).
448	—— Totteniana, *Lea*	N	......	*S. putris*, var.
451	Arion fuscus, *Müll.* (1774)	N	E	Perhaps that species. *A. hortensis*, Férussac (1819).
453	Zonites inornata, *Say*	N	......	*Zonites* is masculine; see De Montfort.
454	—— suppressa, *Say*	N		
454	—— fuliginosa, *Griffith*	N		
457	Tebennophorus dorsalis, *Binn.*	N		
465	Alexia myosotis, *Drap.*	N	E	G. *Melampus*.
466	Carychium exiguum, *Say* (1822)	N	E	*C. minimum*, Müll. (1774).
467	Melampus bidentatus, *Say*	N	......	Specific name preoccupied. *M. corneus*, Desh.
471	Limnæa columella, *Say* (1817)	N	E	*L. peregra*, Müll. (1774).
473	—— decollata, *Migh.*	N	......	*L. catascopium*, var.

Page.	Name of Species.	North or South of Cape Cod.	European.	Synonyms and Remarks.
474	Limnæa ampla, *Migh.*	N		
475	—— elodes, *Say* (1821)	N	E	*L. palustris*, Mull. (1774).
478	—— desidiosa, *Say*	N	......	*L. truncatula*, var.
479	—— catascopium, *Say*	S		
480	—— umbilicata, *Ad.*	N	......	Allied to *L. truncatula*.
481	—— pallida, *Ad.*	N	......	*L. truncatula*, var. *elegans*.
482	—— humilis, *Say* (1822)	N	E	*L. truncatula*, Mull. (1774).
483	Physa heterostropha, *Say* ...	N	......	More nearly allied to *P. rivalis*, Mat. & Rack., than to *P. fontinalis*.
485	— — ancillaria, *Say*	S		
486	Bulinus elongatus, *Say* (1821)	N	E	*Physa hypnorum*, L. (1766).
488	Planorbis trivolvis, *Say*	N		
490	—— lentus, *Say*	N	......	*P. trivolvis*, var.
491	—— bicarinatus, *Say*	N		
492	—— campanulatus, *Say*	N		
493	—— hirsutus, *Gould* (1840) ..	N	E	*P. albus*, Mull. (1774).
494	—— deflectus, *Say*	N	......	*P. albus*, var. *Draparnaldi*.
495	—— exacutus, *Say*	N	.. ...	Allied to *P. nitidus*.
497	—— parvus, *Say* (1817–19) ..	N	E	*P glaber*, Jeffr. (1828).
498	—— dilatatus, *Gould*	N	E	Perhaps introduced into England and naturalized.
499	Segmentina armigera, *Say* ...	N	......	G. *Planorbis*.
501	Ancylus parallelus, *Hald*	N	... ..	Allied to *A. lacustris*.
502	—— fuscus, *Ad.*	N		
504	Diacria trispinosa, *Lesueur* ...	N	E	G. *Carolina*.
504	Psyche globulosa, *Rang*	N		
505	Heterofusus balea, *Moll.*	N	......	G. *Spirialis*.
505	— — retroversus, *Fleming*	N	E	G. *Spirialis*.
507	Clione limacina, *Phipps* (1773)	N	E	*C. papilionacea*, Pallas (1766).
509	Loligopsis pavo, *Les.*	N		
510	Ommastrephes sagittatus, *Fer. & D'Orb.*	N	.. ...	Lamarck's species. G. *Onmatostrephes*.
513	Loligo punctata, *De Kay* . .	S		
514	—— Pealei, *Les.*	N		
516	Spirula fragilis, *St.* (1830) ...	S	.. ...	*S. australis*, Brug. (1789–92).

Report of the Committee for the purpose of investigating the Chemical Constitution and Optical Properties of Essential Oils.

Dr. Gladstone's Report.

Some of the substances prepared and analyzed by Dr. Wright were examined by me for certain physical properties.

The specimens of hydrocarbon derived from nutmeg-oil were perfectly clear and colourless, and had an odour resembling that of turpentine, but more fragrant. The following are the results of the optical examination of three specimens with different boiling-points (under them are given the numbers in my papers in the Chemical Society's Journal for 1864):—

Prepared by	Boiling-point.	Temperature of experiment.	Specific gravity.	Refractive index for A.	Dispersion.	Specific refractive energy.
Wright	163°-164°	25° C.	0·8454	1·4591	·0265	·5438
Ditto	173-175	26 C.	0·8461	1·4655	·0292	·5501
Ditto	177-179	27 C.	0·8480	1·4667	·0306	·5503
Gladstone ...	167	20 C.	0·8518	1·4630	·0284	·5435
Ditto	166	20 C.	0·8527	1·4634	·0274	·5434

The hydrocarbon with the lower boiling-point is evidently different from the specimens distilled at a higher temperature. These show a marked increase in refraction, and one still more marked in dispersion, while there is no corresponding increase in density; in fact they are fully up to, if not above, any of the hydrocarbons of the $C_{10}H_{16}$ type which I have examined. Now if the higher boiling-point be due to the admixture of a body of the composition of $C_{10}H_{14}$, it ought sensibly to diminish instead of increasing the refraction, on the supposition that C and H have the usual values; but if this body belong to the group of aromatic hydrocarbons, and be, in fact, cymene, it will have the precise effect which is found; for cymene gave the following numbers at 11° C.:—specific gravity 0·872; refractive index for A 1·4801; dispersion 0·0329; specific refractive energy 0·5506.

I have already remarked (Chem. Journ. Soc., 1870, p. 151) that all the terpenes give refraction-equivalents a little above the calculated amount, and it might be supposed that this is due to the admixture of some cymene in each instance; but the fact of the same increased refraction occurring in the cedrenes and colophene, which boil at a temperature far above that of cymene, negatives this idea, unless it be supposed that these substances also contain polymerides of cymene, which is not impossible.

The supposed polymerides of myristicol gave the following numbers (under them are given those previously determined for this compound):—

Prepared by	Boiling-point.	Temperature of experiment.	Specific gravity.	Refractive index for A.	Dispersion.	Specific refractive energy.
Wright	212°-218°	24°	0·9407	1·4757	·0271	·5057
Ditto	265-285	25	0·9966	1·4958	·0362	·4975
Ditto	above 300	30	1·0221	1·5319	....	·5204
Gladstone ..	 224	20	0·9466	1·4848	·0312	·5121

The three supposed polymerides are evidently different bodies; but the closeness of the specific refractive energies of the first two confirms the idea of their being identical in ultimate composition. The third is only a little higher, which might easily be accounted for by a somewhat larger proportion of hydrogen.

The body derived from orange-oil, which appeared to be analogous to this higher polymeride of myristicol, was found to be like it in other respects also.

	Temperature of experiment.	Specific gravity.	Refractive index extreme red.	Refractive index for D.	Specific refractive energy for D.
From nutmeg	27°	1·0221	1·5319	1·5376	·5269
From orange	27°	0·9974	1·5195	1·5251	·5265

They have both the same colour, and absorb the more refrangible rays of the spectrum in the same manner. That from nutmeg is somewhat darker and less fluid. They are freely soluble in ether, but not in alcohol. Their general appearance, and the action of alcohol, gave an impression of their being mixtures, such as might be inferred both from the results of analysis and from the specific refractive energy.

A chlorinated product, $4(C_{10}H_{15}Cl)+C_{10}H_{14}$, was found to have a specific gravity of 0·8685 at 24°, a refractive index for A of 1·4755, and a dispersion of 0·326: consequently the specific refractive energy was 0·5475, and the refraction-equivalent for so complicated a formula will amount to 446·7; the usual values of carbon, hydrogen, and chlorine would give only 385·8, and, making the usual addition for phenyl compounds, the refraction-equivalent would only rise to about 420.

A hydrocarbon, apparently possessing the composition $(C_{10}H_{15})_n$, which was found among the products of the reaction of pentachloride of phosphorus on myristicol, was somewhat dark in colour. It had the specific gravity of 0·9515 at 24°, a refractive index for A of 1·5143, and a high dispersion. Its specific refractive energy, 0·5405, is but little short of that found for cymene, viz. 0·5506, and is consistent with the idea of the substance being cymene mixed with some other body not belonging to the phenyl group.

Dr. Wright's Report.

At the last meeting of the Association a preliminary notice was read on the action of certain oxidizing agents on *hesperidene*, the terpene of orange-oil (Portugal of commerce). A large number of further experiments have been made on this essential oil, and also on nutmeg-oil, which is said to contain another terpene (*myristicene*) of boiling-point several degrees lower than than that of hesperidene; there being thus reason for supposing that these two terpenes constitute a well-marked case of isomerism, it was thought best to investigate the oils in which they occur before commencing experiments on other and lesser-known essential oils. In many points the results are not yet quite complete.

The oils employed were obtained from Messrs. Piesse & Lubin, and were believed to be perfectly genuine and unadulterated.

1. *Oil of Nutmeg.*—It has been shown by Gladstone (Chem. Soc. Journ. 1864, p. 1, and 1872, p. 1) that this oil consists essentially of a terpene (*myristicene*) boiling at 167°, together with a small quantity of an oxidized constituent boiling at about 220°, and giving on analysis numbers agreeing badly with the formula $C_{10}H_{14}O$, and thence termed *myristicol*. About a kilogramme of oil was slowly distilled; the majority came over below 200°; some boiled up to 290°, when a soft brown resin was left in the retort, constituting about 2 per cent. of the oil distilled; on combustion this gave numbers agreeing with the formula $C_{40}H_{56}O_5=4C_{10}H_{14}+O_5$.

The higher portions of this first distillate appeared to be somewhat more oxidized than this resin, portions boiling at 260° to 280° and at 280° to 290° giving numbers agreeing with the empirical formula $C_{10}H_{13}O_2$; these substances have not yet been further examined, being probably mixtures.

The lower portions of the first distillate were several times fractionated, with the result of producing a considerable quantity of a mixture of hydrocarbons boiling below 180°, and a small quantity of an oxidized constituent,

the "myristicol" of Gladstone. After several fractionations, however, it became evident that this substance alters by the action of heat upon it, becoming changed, first, into liquids of the same composition but higher boiling-point, and finally into an isomeric resin, not volatile at 300°. The purest unaltered "myristicol" obtained boiled between 212° and 218°: both this and the higher isomerides boiling at 265° to 285° and the resin not volatile at 300° gave on analysis numbers which lay between those required for the formulæ $C_{10}H_{14}O$ and $C_{10}H_{16}O$, more nearly approximating to the latter; from this it is concluded that the "myristicol" of Gladstone is essentially a peculiar kind of camphor, $C_{10}H_{16}O$, which on heating becomes transformed into a mixture of polymerides bearing to it the same relation that the colophenes and cedrenes bear to the terpenes; this conclusion is strongly supported by the physical properties of these polymerides as examined by Dr. Gladstone.

This polymerization by heat of $C_{10}H_{16}O$ bodies probably affords an explanation of the anomalous results obtained in the distillation of certain naturally oxidized essential oils, such as lign aloes, from which no substance of constant boiling-point can be obtained, the distillates obtained in one operation continually altering in another.

The action of phosphorus pentachloride on myristicol has been examined, and appears to be in accordance with the equation

$$C_{10}H_{16}O + PCl_5 = POCl_3 + HCl + C_{10}H_{15}Cl,$$

a reaction indicating that myristicol is a kind of alcohol or phenol, *i. e.* that it may be written $\left.\begin{matrix} C_{10}H_{15} \\ H \end{matrix}\right\} O$. The resulting product $C_{10}H_{15}Cl$ is difficult to obtain even approximately pure, as the action of heat causes it to split up into HCl and $C_{10}H_{14}$. The hydrocarbon thus formed has not yet been thoroughly examined; a considerable quantity of it becomes polymerized at the moment of its formation into a yellow-brown viscid resin, not volatile at the extreme limit of the mercurial thermometer, and having apparently the composition $(C_{10}H_{15})_n$. It is proposed to obtain myristicol in larger quantities, and to examine more fully this action, and also the action of phosphoric anhydride &c. on it. Camphor gives rise, by the action of dehydrating agents, to cymene, $C_{10}H_{14}$; it will be of interest to determine whether such a reaction takes place with myristicol, and if so whether the same cymene is formed.

The hydrocarbons contained in the nutmeg-oil distillates boiling below 180° were heated for some time in contact with sodium, and submitted to careful fractional distillation over that metal for several weeks; finally the whole was almost entirely split up into two portions—one constituting about three fourths of the whole and boiling at 163° to 166°, and the other, about one sixth as large in quantity, boiling at 173° to 177°. Intermediate fractions were at first obtained; but by successive distillations these split up almost entirely into the higher and lower fractions. A small quantity was also obtained boiling above 177°; but this contained a minute quantity of an oxidized constituent not destroyed by the sodium, distillates at 179° to 181° and 181° to 185° giving numbers on analysis adding up to 98·6 and 98·8 respectively:—

The following percentages were obtained with the fractions that were free from oxidized substances:—

Boiling-point	163°–164°C.	164°–166°	173°–175°	175°–177°	177°–179°
Per cent. carbon ...	88·24	88·28	88·35	88·04	88·12
Ditto hydrogen ...	11·89	12·08	11·71	11·61	11·67

The formula $C_{10}H_{16}$ requires carbon=88·23, hydrogen=11·77; while $C_{10}H_{14}$ requires carbon=89·55, hydrogen 10·45.

From these numbers it is inferred that nutmeg-oil contains at least two terpenes, one boiling at about 164°, the other at about 176°, or 12° higher, the former predominating, and the "myristicene" of Gladstone, boiling at 167°, being a mixture of the two. The lowest of these two terpenes does not appear to be mixed with any great quantity of a lower hydrocarbon, such as $C_{10}H_{14}$, but is not necessarily free from such admixture; for quantities of 9 and even 14 per cent. of $C_{10}H_{14}$ in the mixture produce very little alteration in the calculated numbers, requiring respectively C=88·36, H=11·64, and C=88·42, H=11·58. The higher hydrocarbon, however, contains certainly a considerable percentage of $C_{10}H_{14}$ (probably cymene, which boils at about 176°); for the observed numbers are uniformly short of the hydrogen percentage required for $C_{10}H_{16}$, and coincide precisely with those that would be furnished by a mixture containing 20 or even 25 per cent. of cymene, such mixtures requiring respectively C=88·49, H=11·51, and C=88·56, H=11·44.

As shown in section 4, the 163°–164° fraction yielded by careful oxidation by nitric acid 13·2 per cent. of a mixture of toluic and terephthalic acid, in the proportion of 1 of the former to 4 of the latter; if it be assumed that these acids arose solely from the oxidation of cymene, $C_{10}H_{14}$, present in the hydrocarbon employed, this would indicate the presence of at least 11·1 per cent. of cymene in the hydrocarbon, a quantity which, as just shown, is less than that which might be present without being appreciable by ordinary analysis. The quantity of toluic + terephthalic acids yielded by the fractions boiling at 175°–177° has not yet been accurately determined, but it appears to be greater than that obtained from the lower fraction. The general conclusion drawn from all this is, that it is not at all improbable that the terephthalic acid produced by the oxidation of various terpenes, such as oils of turpentine, lemons, &c., is derived, *not from the $C_{10}H_{16}$ present in the hydrocarbon used, but from the admixture of a certain amount of cymene in the substance employed*, and that, in consequence, the supposed identity of such hydrocarbons and their relations to benzene are by no means proven—a conclusion strengthened by the results obtained with the orange-terpene, hesperidene, from which no terephthalic acid at all is derivable by oxidation, although otherwise its oxidation-products very much resemble those of the other terpenes.

2. *Oil of Orange-peel* (Portugal of commerce).—On slow distillation of this oil the majority came over below 180°; a few drops of oxidized product came over at 240°–250°, agreeing with the formula $C_{40}H_{64}O_3 = 4C_{10}H_{16} + O_3$; and a small quantity, 2·8 per cent., of a non-volatile inodorous resin was left behind, agreeing with the formula $C_{20}H_{30}O_4 = 2C_{10}H_{16} + O_4$.

Like the nutmeg-oil, there is present a substance boiling at 210°–220°, giving numbers agreeing nearly with the formula $C_{10}H_{16}O$, and converted by heat into an isomeric non-volatile resin: the sole difference observed between this body and the nutmeg-myristicol is in smell, the one smelling of nutmeg and the other of orange-peel; the small proportions in which it exists in orange-oil has prevented any minute examination of it as yet.

Fully 95 per cent. of the oil is a hydrocarbon which, after many distillations over sodium, boils constantly at 178° (corrected); Gladstone finds that hesperidene boils at 174°.

This is a terpene, as it gave on analysis carbon=88·17, hydrogen=12·06, while $C_{10}H_{16}$ requires C=88·23, H=11·77.

It is evident that this body is not identical with the lower nutmeg-turpene boiling at 164° or so; but there appears to be some relation between them, both yielding products of similar character by oxidation; the orange-terpene, however, giving no terephthalic acid, from whence it appears that the hydrocarbon is free from cymene.

3. *Action of Potassium Dichromate and Sulphuric acid on Nutmeg- and Orange-Terpenes.*—As mentioned in a preliminary note read before the Association last year, acetic acid is produced by the action of these substances on hesperidene along with carbonic and formic acids. Barium and silver acetate have been prepared and analyzed. The portion of oil apparently not attacked was found on distillation to contain an oxidized substance not volatile below 200° (the hydrocarbon used was *wholly* volatile below 178°, and contained no trace of oxidized substance); on distillation this gave a few drops boiling at 210°–230°, and a resin not volatile at 300°, and giving numbers agreeing with the formula $C_{20}H_{28}O = C_{10}H_{16}O + C_{10}H_{14}O - H_2O$. The distillate at 210°–230°, on continued heating, acquired a higher boiling-point and became resinized; products boiling at 210°–230° in two different experiments, and a polymerized portion produced from the two jointly, and boiling at 240°–250°, all gave numbers almost identical with those given by myristicol, and closely approximating to those required for $C_{10}H_{16}O$. From these numbers, and the peculiar and apparently characteristic properties of the substance, it is inferred that a liquid camphor of formula $\left.\begin{matrix}C_{10}H_{15}\\H\end{matrix}\right\}O$ has been produced from a hydrocarbon, $C_{10}H_{15}H$, by direct oxidation; in other words that an action of a type hitherto wanting has been found, viz. the *conversion of a hydrocarbon into one of the corresponding alcohols by direct oxidation*: hitherto this has been only accomplished by circuitous processes, such as forming a chloro- or sulphuric derivative, &c., and the conversion of this into the hydroxyl derivative by treatment with silver salts or potassium acetate and caustic potash, &c. From a theoretical point of view, the interest attaching to this reaction is great, as it exhibits closely the mutual relations of hydrocarbon, primary alcohol, ortho-aldehyde, and ortho-acid, thus:—

Hydrocarbon	$X^1 . CH_3 + O$	=	$X^1 . CH_2OH$	..Primary alcohol.
Primary alcohol..	$X^1 . CH_2OH + O$	=	$X^1 . CH(OH)_2$	..Ortho-aldehyde.
Ortho-aldehyde ..	$X^1 . CH(OH)_2$	=	$X^1 . C(OH)_3$	..Ortho-acid.

each substance being derived from the preceding one by conversion of H into OH by direct oxidation.

During the last few weeks it has been shown by Oppenheim (Deut. Chem. Ges. Ber. v. 631) that by the action of sulphuric acid and potassium dichromate on the hydrocarbon $C_{10}H_{14}$, obtained by heating aniline and the terpene dibromide from oil of lemons (Citronenöl), there are produced acetic acid, terephthalic acid, and a body, $C_{10}H_{16}O$, apparently identical with ordinary camphor. Schwanert (Ann. Chem. Pharm. cxxviii. 77) found that oil of lemons gave terephthalic acid on oxidation with nitric acid. Inasmuch as hesperidene has been found to yield no appreciable trace of terephthalic acid either by the action of nitric acid or by that of sulphuric acid and potassium dichromate, it appears that the terpene of orange-rind and that of the lemon-rind are not identical; the results obtained with the nutmeg-oil, however, render it not improbable that the real source of terephthalic acid is cymene contained in small quantities in the hydrocarbon examined, and that many of the terpenes hitherto described are mixtures of two or more hydrocarbons. It would be desirable to have this point cleared up both in the case of ordinary

turpentine and oil of lemons, as well as other terpenes, as much stress has been laid on the production of terephthalic acid and of cymene from these hydrocarbons and their derivatives.

The preceding experiments render it probable that the gradual resinizing which occurs in terpenes on keeping arises from a spontaneous absorption of oxygen and the consequent formation of the resinous polymerides $(C_{10}H_{16}O)_n$.

On treating the lowest hydrocarbon (b.-p. 163°-164°) obtained from nutmeg-oil in the same way as the hesperidene, precisely the same results were obtained, with the sole difference that a little terephthalic acid was also formed, which was not the case with the orange-hydrocarbon.

The chromic liquor gave an acid distillate which contained acetic and probably formic acids; barium and silver acetates were analyzed, and the apparently unattacked hydrocarbon left on distillation a few drops boiling at upwards of 210°, and giving numbers on analysis identical with those given by myristicol, by the oxidized constituent of orange-oil distilling at 210° to 230°, and by the similarly obtained oxidation-product of hesperidene just described. Whether these four substances are identical or not cannot be decided; but the only difference noticeable between them was in the matter of odour, each one being different from the others in this respect.

The action of the chromic liquor on the higher boiling hydrocarbon of nutmeg-oil has not yet been examined.

4. *Action of Nitric Acid on Nutmeg- and Orange-Terpenes.*—Schwanert has shown (Ann. Ch. Pharm. cxxviii. 77) that where camphor and certain other analogous substances are treated with nitric acid, there is produced, *inter alia*, a non-crystalline acid, *camphresinic acid*, $C_{10}H_{14}O_7$, which same acid also results when certain terpenes (*e. g.* Citronenol) are oxidized in the same way. Kachler, however, has recently found (Ann. Ch. Pharm. clix. 281) that the so-called camphresinic acid from camphor is a mixture, the principal constituent of which is a crystallizable acid, $C_9H_{12}O_5$, to which he gives the name *camphoronic acid*; this is characterized by giving a sandy precipitate *on boiling* a neutral solution of its ammonium salt with barium chloride, from which precipitate the acid is obtainable.

On boiling hesperidene with from eight to ten times its volume of a mixture of nitric acid diluted with its own bulk of water, a vigorous reaction sets in; red fumes and carbonic acid are copiously evolved, and after some time a brown resinous substance is formed, which on further treatment with stronger acid mostly becomes soluble: a small quantity of yellow resinous substance is, however, left, much resembling the crude terephthalic acid obtained by the similar treatment of nutmeg-oil; this substance mostly dissolves in ammonia; but on digesting the dark solution with purified animal charcoal, *the whole is gradually absorbed*, nitric acid finally giving no precipitate whatever in the filtrate. A portion of the filtrate was precipitated before the total absorption had taken place; the trifling amount of flakes obtained gave numbers on combustion very far from those required for terephthalic acid, and nearly the same as those given by the yellow resinous substance before treatment with ammonia and animal charcoal.

Crude yellow resin gave carbon	46·1	Hydrogen..	4·4
Ditto partially purified by charcoal	47·7	„	4·6
Terepththalic acid requires	57·8	„	3·6

From this it is inferred that the yellow resin was not terephthalic acid, and that this body is not produced by the oxidation of hesperidene by nitric acid (nor was it formed with chromic liquor as described in the last section).

Even had this yellow resin been pure terephthalic acid it would not have amounted to more than 0·3 per cent. of the hydrocarbon used.

The nitric-acid solution was evaporated to dryness, the residue neutralized by ammonia, and barium nitrate added in the cold; a copious precipitate of oxalate was obtained, from which pure oxalic acid and calcium and silver oxalates were procured and analyzed. The filtrate on boiling gave a trifling sandy precipitate, which was nothing but oxalate; no trace of Kachler's camphoronic acid could be detected.

The filtrate was precipitated by lead acetate, the copious precipitate well washed and decomposed by sulphuretted hydrogen, and the evaporated solution thus obtained extracted with ether; after evaporation a yellow sour syrup was obtained, which, on standing for several months over sulphuric acid, refused to deposit crystals, but gradually thickened, and finally became a semisolid mass much resembling soft toffy: no crystals could be obtained by pressure in blotting-paper. On combustion this gave numbers indicating approximately the formula $C_{20}H_{28}O_{19}$, but differing considerably from those required for either camphresinic or camphoronic acids. Converted into calcium salt a gummy salt was obtained, which, after drying at 160°, contained 18·1 to 18·5 of calcium. On dissolving this in water and precipitating by alcohol a calcium salt was thrown down resembling the original one in all respects, but containing 20·8 per cent. of calcium after drying at 160°. From this it appears that the syrupy toffy-like acid was a mixture. The isolation of the constituents of this mixture has not yet been finished.

On treating the 163°–164° nutmeg-terpene in the same way, precisely similar results were obtained, with this difference, that the brown resinous product formed after the action had gone on for a short time was converted, by longer treatment, into a yellow resin, which, after purification by solution in ammonia, treatment with animal charcoal, and precipitation of the nearly decolorized solution by nitric acid, furnished a mixture of toluic and terephthalic acids. In one carefully conducted quantitative experiment, 105·8 grammes of pure hydrocarbon gave 14·0 of a mixture which, on analysis, appeared to contain the acids in the proportions denoted by $4C_8H_6O_4+C_8H_8O_2$; *i. e.* the mixture was 13·2 per cent. of the hydrocarbon. In other experiments, with the mixture of hydrocarbons boiling below 180° contained in the nutmeg-oil, 17 to 18 per cent. of a mixture of $C_8H_6O_4$ and $C_8H_8O_2$ in nearly equal proportions was obtained.

It was found difficult to separate completely the toluic and terephthalic acids by boiling water or alcohol, in which the latter is much the least soluble; but approximately pure specimens of each acid were isolated and recognized by combustion, properties, and preparation of barium salts.

The nitric-acid solution was found to contain oxalic acid, recognized by its properties and the analysis of its calcium salt; this was separated, and the filtrate treated in the manner above described; finally a syrupy toffy-like acid was obtained, much resembling that from hesperidene. This gave numbers agreeing with the formula $C_{10}H_{14}O_9$; on conversion into calcium salt and precipitation by alcohol, a substance was obtained which, after drying at 160°, contained 20·4 per cent. of calcium The examination of these products is not yet concluded.

5. *Action of Hydriodic Acid on Hesperidene.*—Gaseous hydriodic acid was passed into hesperidene till saturated; the substance remained liquid: after agitation with dilute caustic soda the liquid boiled at near 220°, with partial decomposition, and gave numbers indicating the compound $C_{10}H_{16}HI$ mixed with some unaltered hydrocarbon.

In order to add on hydrogen to hesperidene, this crude hydriodide was heated with phosphorus and water in a sealed tube at 130°–150°. Much phosphine and phosphonium iodide were produced, and several times the tubes exploded; a polymeride of $C_{10}H_{16}$, however, was the sole resulting organic substance.

The same result was obtained on boiling with phosphorus the crude hydriodide, an inverted condenser being attached. After some time the contents of this flask were distilled and found to consist only of $C_{10}H_{16}$ + $C_{10}H_{17}I$; the last few drops in the retort boiled at about 250°; boiling alcohol dissolved the fluid sparingly (cold alcohol dissolved only traces). A few drops of an oily hydrocarbon deposited on cooling; on combustion this gave carbon 88·5, hydrogen 11·4: total 99·9.

The formula $(C_{10}H_{16})$ requires carbon 88·2, hydrogen 11·8; whence it appears that the hesperidene has become polymerized, the boiling-point being raised about 75°. Gladstone has shown that $C_{15}H_{24}$ polymerides boil near 250°; the analysis indicates rather a subtraction than an addition of hydrogen, $C_{15}H_{23}$ requiring carbon 88·7, hydrogen 11·3.

In the hope of obtaining a C_{11} acid, the hydriodide was boiled with alcohol and silver cyanide for several hours: silver iodide was copiously produced, and the liquid acquired a peculiar odour recalling that of the nitriles.

On boiling with alcoholic potash, ammonia and methylamine were given off, a thick brown carbonized resin was formed, and, in very small quantity, the potash salt of an acid soluble in ether; this acid gave a yellowish-white flocculent precipitate with lead acetate: just sufficient of this lead salt was obtained for one determination, which gave lead =54·6 per cent. Probably this was a basic salt; the anticipated reactions

$$\begin{aligned} C_{10}H_{16}+HI \;\ldots\ldots\ldots &= C_{10}H_{17}I \\ C_{10}H_{17}I+AgCN \;\ldots\ldots &= C_{10}H_{17},CN+AgI \\ C_{10}H_{17}CN+2H_2O \;\ldots\ldots &= NH_3+C_{10}H_{17},CO,OH \end{aligned}$$

indicate the formation of an acid, the neutral salt of which would require 36·3 per cent. lead, while the basic salt $(C_{11}H_{17}O_2)_2Pb,PbO$ would require 53·7.

It is proposed to examine further the questions of the synthesis of acids from the different terpenes, by means of the hydrogen chloride or hydrogen bromide compounds.

Appendix.—Since the reading of the above Report, some further experiments have been made on the existence of cymene as a natural constituent of what have been hitherto considered to be pure terpenes: by treating such terpenes with sulphuric acid, the $C_{10}H_{16}$ constituents are polymerized, whilst cymene, if present, is mainly unaltered and can be obtained by distilling the acid liquor in a current of steam. By these means it has been found that the lowest-boiling nutmeg-hydrocarbon actually does contain cymene; also that cymene is present in ordinary oil of turpentine; on the other hand, no trace of cymene is contained in hesperidene, a fact the more remarkable as pure cymene is obtainable in quantity by heating the product of the action of bromine on hesperidene, viz. $C_{10}H_{16}Br_2$, which splits up thus—

$$C_{10}H_{16}Br_2=2HBr+C_{10}H_{14}.$$

Apparently the cymene thus produced, that precontained in nutmeg-oil and oil of turpentine, that derived from camphor and various other varieties now undergoing examination are identical.

The action of zinc chloride on myristicol yields the same cymene together with another product.

The acids obtained by the action of nitric acid on hesperidene and myristicene, as described in the above report, have been obtained in the pure state, and are represented by the formulæ—

	Dried at 100°.	Dried over sulphuric acid.
Acid from hesperidene	$C_{20}H_{26}O_{17}$	$C_{20}H_{24}O_{17}$, $2H_2O$
Acid from myristicene	$C_{20}H_{26}O_{16}$	$C_{20}H_{26}O_{16}$, $2H_2O$

It is hoped that a report on these and other points will be presented at the next Meeting of the Association.

C. R. A. Wright.

St. Mary's Hospital, Feb. 28, 1873.

Report of the Committee, consisting of the Rev. Canon Tristram, Professor Newton, H. E. Dresser, J. S. Harting, *and the* Rev. A. F. Barnes, *appointed for the purpose of continuing the investigation on the desirability of establishing a "Close Time" for the preservation of indigenous animals.*

1. Believing that the time had come for advantageously urging the Legislature to take further action whereby the objects for which your Committee was appointed might be promoted, your Committee, after due consideration, prepared a Bill, intituled an Act for the Protection of Wild Fowl, which being entrusted to the care of Mr. Andrew Johnston, M.P., was by him, Colonel Tomline, M.P., and Mr. Brown, M.P., brought into the House of Commons on February 15th, and read the first time.

2. This Bill was based entirely on the 'Sea-Birds' Preservation Act' of 1869, and, *mutatis mutandis* only, strictly followed the provisions of that Act, which experience has shown to have fully effected the object for which it was passed, and to have given very general satisfaction to the country at large.

3. On the motion for the second reading of the Bill in the House of Commons, June 12th, the Hon. Auberon Herbert, M.P., proposed as an amendment that it was "desirable to provide for the protection of all wild birds during the breeding-season;" but this amendment, which would have been fatal to the Bill, was withdrawn; the Bill was read a second time and ordered to be committed, June 21st.

4. In the debate in the House of Commons on the notice for going into Committee, Mr. Herbert moved, according to notice, "That it be an instruction to the Committee that they have power to extend the protection, given under the Bill to Wild Fowl during the breeding-season, to other wild birds." The House divided: Ayes 20, Noes 15; and thereupon Mr. Herbert moved a number of other amendments of which he had given notice; and these being accepted by the House, the Bill, instead of being the moderate measure contemplated by your Committee, became one of general and indefinite scope.

5. By this means the fate of the Bill, which had hitherto met with no serious opposition, was rendered very uncertain, and notice was given of a motion to throw it out; but on the report being taken, the Bill, on Mr. Johnston's proposal, was referred to a Select Committee, by whom it was still further modified, the objections urged against its sweeping clauses being overcome by limiting its effects to certain kinds of birds named in a Schedule,

while the penalties for its infringement were diminished. In this form it went back to the House of Commons, and with a few other alterations finally passed that House, and was sent to the House of Lords.

6. In the Upper House charge of the Bill was taken by the Earl of Malmesbury, and, some fault being found with it, its provisions were further altered in Committee, a person convicted of a first offence being rendered liable to a reprimand and the payment of costs and summons only. Thus modified it was returned to the House of Commons, and has since received Her Majesty's assent.

7. Your Committee cannot look with unmixed favour on this measure. It appears to them to attempt to do too much, and not to provide effectual means of doing it. In their former Reports they have hinted at, if not expressed, the difficulty or impossibility of passing any general measure, which, without being oppressive to any class of persons, should be adequate to the purpose. Further consideration has strengthened their opinion on this point. They fear that the new Act, though far from a general measure, will be a very inefficient check to the destruction of those birds, which, from their yearly decreasing numbers, most require protection, its restraining power having been weakened for the sake of protecting a number of birds which do not require protection at all. Your Committee have never succeeded in obtaining any satisfactory evidence, much less any convincing proof, that the numbers of small birds are generally decreasing in this country. On the contrary, they believe that, from various causes, many if not most species of small birds are actually on the increase. They are therefore of opinion that an Act of Parliament proposing to promote their preservation is a piece of mistaken legislation, and is mischievous in its effect, since it diverts public attention from those species which, through neglect, indifference, custom, cupidity, or prejudice, are suffering a persecution that will in a few years ensure their complete extermination. At the same time your Committee are glad to state that such protection as is afforded by the new Act will be extended to the particular group of birds which in former Reports they have shown to require it most, all the Wild Fowl named in the Bill prepared by your Committee having been included in the schedule of the Act. It is also gratifying to your Committee to find that the principle of a "Close Time" for all birds has been admitted by the House of Commons, though the application of that principle may at present be inexpedient. Your Committee therefore trust that the Act will not be otherwise than beneficial in its results; and though greatly indebted to many noblemen and gentlemen for the assistance they have rendered, your Committee cannot refrain from especially thanking Mr. Andrew Johnston for the skill and patience he has shown in the conduct of the Bill introduced.

8. Your Committee respectfully suggest that they may be reappointed.

Sixth Report of the Committee appointed for the purpose of continuing Researches in Fossil Crustacea, consisting of Professor P. MARTIN DUNCAN, *F.R.S.,* HENRY WOODWARD, *F.G.S., and* ROBERT ETHERIDGE, *F.R.S. Drawn up by* HENRY WOODWARD, *F.G.S.*

SINCE I had the pleasure of presenting my last Report at Edinburgh, I am glad to be able to state that two entire parts (Parts III. and IV.) of my Mono-

graph on the MEROSTOMATA have been printed, and form part of the volumes of the Palæontographical Society's annual fasciculus for 1871 and 1872 respectively.

Part III. completes the genus *Pterygotus*, and contains descriptions and figures of:—

Pterygotus raniceps. Upper Silurian, Lanark.
—— *taurinus*. Ditto, Herefordshire.
—— *ludensis*. Old Red Sandstone, Kington, Herefordshire.
—— *Banksii*. Upper Ludlow, Ludlow.
—— *stylops*. Upper Silurian, Kington, Herefordshire.
—— *arcuatus*. Lower Ludlow, Leintwardine.
—— *gigas*. Downton Sandstone, Hereford.
—— *problematicus*. Upper Ludlow, Ludlow.
Slimonia acuminata. Upper Silurian, Lesmahagow.

Part IV. completes the suborder EURYPTERIDA, and contains descriptions and figures of the following genera and species:—

Stylonurus Powriei. Old Red Sandstone, Forfar.
—— *megalops*. Ditto, Ludlow.
—— *Symondsii*. Ditto, Rowlestone, Herefordshire.
—— *ensiformis*. Ditto, Forfar.
—— *scoticus*. Ditto.
—— *Logani*. Upper Silurian, Lanark.
Eurypterus Scouleri. Carboniferous Limestone, Kirkton, Bathgate.
—— *lanceolatus*. Upper Silurian, Lanark.
—— *pygmæus*. Upper Ludlow, Kington.
—— *acuminatus*. Ditto, Ludlow.
—— *linearis*. Ditto.
—— *abbreviatus*. Downton Sandstone, Kington.
—— *hibernicus*. Old Red Sandstone, Ireland.
—— *Brewsteri*. Ditto, Arbroath.
—— *scorpioides*. Upper Silurian, Lanark.
—— *punctatus*. Ludlow Rock, near Ludlow.
—— *obesus*. Upper Silurian, Lanarkshire.
—— *Brodiei*. Ditto, Herefordshire.
Hemiaspis limuloides. Upper Ludlow, near Ludlow.
—— *speratus*. Lower Ludlow, ditto.
—— *horridus*. Wenlock Limestone, Dudley.
—— *Salweyi*. Upper Ludlow, Ludlow.

Two doubtful species of *Eurypterus*, namely *E. mammatus*, from the Coal-measures near Manchester, and *E. ferox*, Coal-measures, Coalbrookdale and Staffordshire Coal-field, have been examined critically; and with regard to *E. mammatus*, I have also had the great advantage of the assistance and rare palæobotanical knowledge of my colleague, Mr. W. Carruthers, F.R.S.

A careful examination of the original specimens of *E. mammatus* has enabled me to show that four out of the six specimens known and referred by the late Mr. Salter to the genus *Eurypterus* are *plant-remains*, referable to the genus *Ulodendron* or to fragments of a large Equisetaceous plant, and that the two remaining parts appear to belong to Jordan and Von Meyer's genus *Arthropleura*, a nondescript crustacean (or, more probably, a gigantic arachnid), only known at present by a series of obscure fragments from Saarbruck, from Manchester, and from Camerton Colliery, near Bristol.

The ornamentation as well as the form of these pieces are totally unlike any known *Eurypterus*.

Of *Eurypterus ferox* I am now able to state that it is not a Eurypterid, but is referable to Messrs. Meek and Worthen's American genus *Euphoberia*, and that it is a gigantic MYRIOPOD, much larger than our largest tropical

living species of *Julus* or Centipede. This is the second species of Myriopod occurring in the Coal-field of Illinois, U.S., which has since also been obtained in England.

Of the Merostomata only the suborder Xiphosura remains to be monographed, a task which I hope to complete during the present year.

At the beginning of this year I was requested by Robt. Etheridge, Jun., Esq., F.G.S. (of the Geological Survey of Scotland), to examine some specimens of *Ceratiocaris* from Lesmahagow, Lanarkshire. Among them was one to which he specially drew my attention, as it presented the novel appearance of appendages on the underside of the caudal series of segments. These consist of gill-like plates depending freely from each segment. They are no doubt analogous to those seen in *Nebalia*, which are supplementary abdominal gill-feet. The discovery of these organs by Mr. Etheridge, which occur also in several other specimens, does not in any way alter the position of *Ceratiocaris*, but renders our knowledge of it more complete.

Since Mr. Salter's paper "On *Peltocaris*, a new genus of Silurian Crustacea," was published in 1863 (Quart. Journ. Geol. Soc. vol. xix. p. 87), I announced a second genus, *Discinocaris*, in 1866 (see Quart. Journ. Geol. Soc. vol. xxii. p. 503), also from the Llandeilo flags of Dumfriesshire. Mr. Charles Lapworth, Mr. J. Wilson, Mr. Robert Michie, and others have added several fine examples of this type of Phyllopodous Crustacea. The largest of these is a portion of a carapace from Dobb's Linn, Moffat, Dumfriesshire, and appears to agree best with *Discinocaris*; but instead of being a carapace the size of a threepenny piece, like *Discinocaris Browniana*, described by me in 1866, this specimen, with its characteristic markings, gives evidence of an individual 7 inches in diameter. Another specimen of this same gigantic Phyllopod was obtained from Moffat by Robert Etheridge, jun., Esq., F.G.S., of the Geological Survey of Scotland.

An entire carapace (of which three examples have been obtained), from the Riccarton Beds, Yads Lynn, near Hawick, makes us acquainted with a new genus, for which the name *Aptychopsis* is proposed.

It measures $1\frac{1}{2}$ in. in length and $1\frac{3}{8}$ in. across.

The nuchal suture is straight (not semicircular, as in *Peltocaris*), and it has a well-marked dorsal suture, which again separates it from *Discinocaris*, in which the dorsal suture is absent.

I name this species *Aptychopsis Wilsoni*, after its discoverer.

Another and more oval-formed but equally perfect carapace of a smaller species, from the Moffat Anthracitic Shales, measuring 8 lines long by 7 lines broad (having the triangular cephalic plate *in situ*), I have named *Aptychopsis Lapworthi*, after Mr. Lapworth, who has devoted so many years to the investigation of the geology of Galashiels and the surrounding district.

A third species, very distinct from the foregoing two, obtained from the Buckholm Beds (which is finely striated concentrically, and is 7 lines in diameter), I have named *Aptychopsis glabra*.

There are several other examples from this rich locality, including specimens of *Peltocaris aptychoides*, species of *Dithyrocaris*, *Ceratiocaris*, and portions of the scale-marked integument of *Pterygotus*.

I have lately received from Mr. Thomas Birtwell, of Padiham, Lancashire, two specimens of a new Limuloid crustacean, in which all the thoracico-abdominal segments are welded together into one piece, as in the modern *Limulus*, but without any trace of segmentation along the margin.

The head-shield is also smooth, the compound eyes are small, but the larval ocelli are very distinctly seen, and are almost as large as in the modern king

crabs. The specimen is only 8 lines wide and 8 long; it is remarkably convex in proportion to its size. I have named it after its discoverer *Prestwichia Birtwelli* (see Geol. Mag. 1872, vol. ix. p. 440, pl. 10. figs. 9, 10).

Another new Limuloid crustacean, specimens of which have been obtained from the Dudley Coal-field, and also from Coalbrookdale, has the five thoracic segments free and movable (as in *Bellinurus bellulus* of Konig), but the pleuræ are bluntly acuminate, not finely pointed, as in *B. bellulus*, and the head-shield is not armed with long and pointed cheek-spines, as in that species.

I propose to name it *Bellinurus Königianus*, after the distinguished author of the 'Icones Fossilium sectiles,' formerly Keeper of the Mineral and Fossil Collections in the British Museum (see Geol. Mag. 1872, vol. ix. p. 439, pl. 10. fig. 8).

Of foreign Palæozoic Crustacea, a remarkable new Trilobite (obtained by Dr. W. G. Atherstone, of Graham's Town, Cape Colony), from the Cock's-comb Mountains, South Africa, deserves to be noticed here. It is a new and elegant species of *Encrinurus* (measuring 3 inches in length), preserved in the centre of a hard concretionary nodule, which has split open, revealing the Trilobite itself in one piece and a profile of it on the other. The profile shows that each of the eleven free body-segments was armed with a prominent dorsal spine nearly half an inch in length, whilst the pygidium was similarly terminated by an even longer spine, slightly recurved at its extremity, and all of the spines *annulated*, as if composed of a large number of *joints*. *Encrinuri* with two (and in one case even with *three*) dorsal spines have been obtained in considerable numbers, both at Dudley and Malvern, and may be seen in Dr. Grindrod's collection, and in the British Museum and many other places; but a Trilobite with such an array of long dorsal spines as is presented by this African species is very remarkable, and for an *Encrinurus* quite unique. I have named it after its locality *E. crista-galli*, which is doubly appropriate (see Quart. Journ. Geol. Soc. vol. xxix. p. 32).

Among the specimens sent me up by Mr. Birtwell from Lancashire, from the *Ironstone* of the Coal-measures (so rich in organic remains), was one not referable to the Crustacea.

On examination it proves to be a new and very remarkable Arachnid, referable to the same genus as one described by Mr. Samuel Scudder, of Boston, U.S., from the Illinois Coal-field, under the name of *Architarbus* (see Meek and Worthen's Report on the Geology and Palæontology of Illinois).

I have named it *Architarbus subovalis* (see Geol. Mag. 1872, vol. ix. p. 385, pl. 9).

This is the second British Arachnid I have lately obtained from the Ironstone of the Coal-measures.

Tertiary Crustacea.—Some time since I described two new forms of Crabs * from the Lower Eocene, Portsmouth, discovered by Messrs. Meyer and Evans in the excavations for the new Docks there. More recently I have received a fresh series, from which I have been enabled not only to refigure and to fully describe the species named by me (on December 21, 1870) *Rhachiosoma bispinosa*, and to show both the upper and under side of the male and female, but also to record two additional forms, for which I propose the genus *Litoricola*, naming them respectively *L. glabra* and *L. dentata*. These do not belong (like *Rhachiosoma*) to the Portunidæ, but to the Ocypodidæ, or

* *Rhachiosoma bispinosa* and *R. echinata* (see Quart. Journ. Geol. Soc. 1871, vol. xxvii. p. 91, pl. 4).

true shore-crabs, their legs being adapted for running, and their eyes furnished with long peduncles* (see Quart. Journ. Geol. Soc. vol. xxix. p. 28).

This series of Crustacea (though they are exceedingly brittle and delicate) are remarkable for the perfect state of preservation in which they occur, so that we are able in each case to restore nearly the entire animal. Of the two new ones, it is interesting to record that they afford evidence of unmistakable land conditions, both of them being shore-dwellers and adapted for running on the old muddy and sandy beaches of the pre-Eocene continent. The sections still, I believe, open at Portsmouth deserve an inspection from all who are interested in the stratigraphical geology of this series of deposits.

Miocene Crustacea.—Having been requested by Dr. A. Leith Adams, F.R.S., to examine and describe a series of crustacean remains from the Miocene of Malta, collected by him in that island, I have done so, and find them to include *Scylla*, *Ranina*, *Portunites*, *Maia*, *Atergatis*, and perhaps *Neptunus*. The *Scylla* agrees specifically with the *Scylla serrata* found in the Indian seas of to-day and in the Tertiaries of the Philippine Islands. This is one of the species of fossil crabs so largely imported into China as "Medicine-Crabs" (see Mr. D. Hanbury's papers read before the Pharmaceutical Society, and published in their Journal, February 1862 *et seq.*).

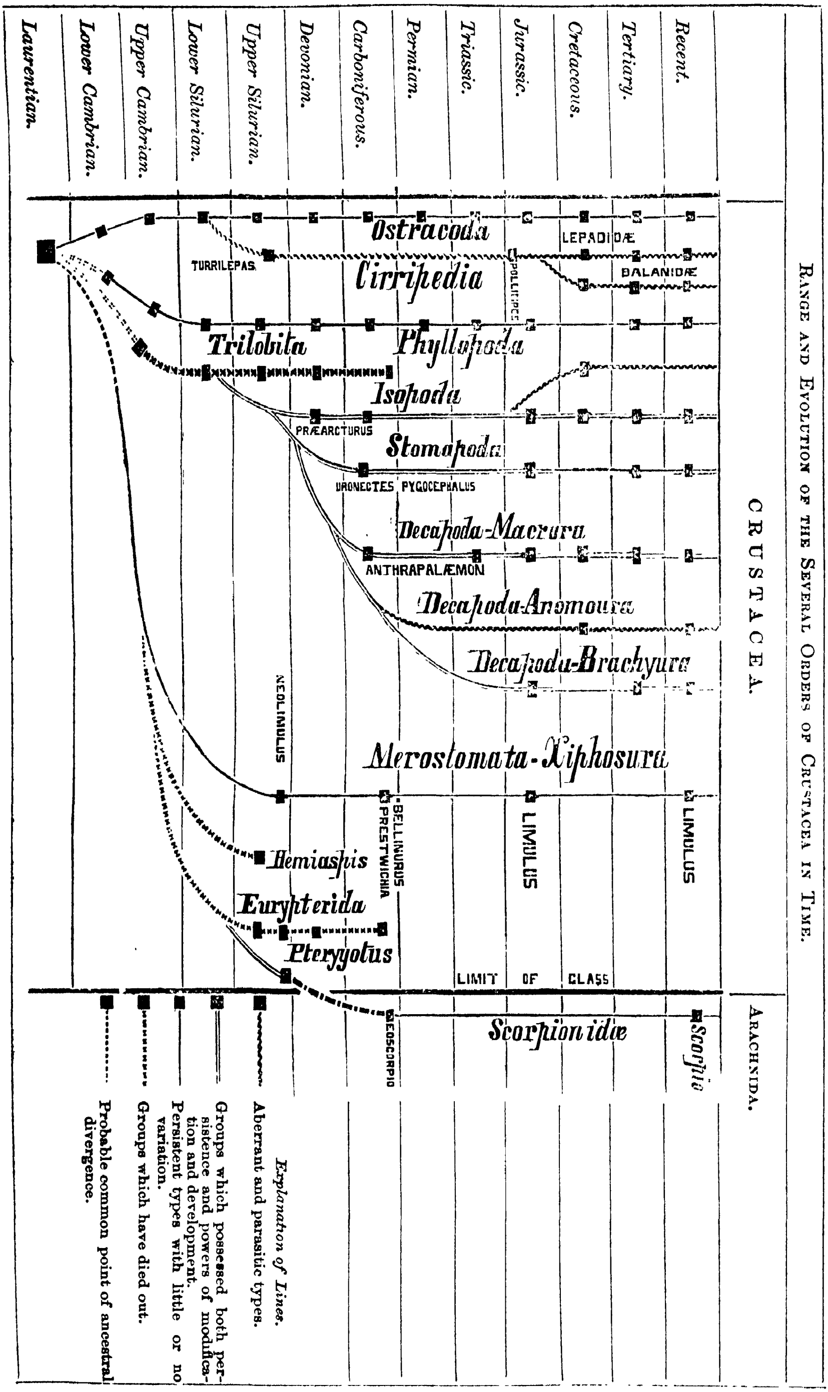
The *Ranina* is distinct from any recorded species, and I have therefore to propose for it a specific name. I dedicate it to its discoverer (*R. Adamsi*).

The occurrence of these Eastern forms, with the remarkable Echinoderms of Asiatic type, in Malta, clearly indicate the former extension of an Indian fauna as far east as the Mediterranean, if not to our own shores.

Whilst still pursuing the subject of the structure of the Trilobites, no new facts have been collected; but much has been done in the examination of larval *Limulus*, the substance of which I have summarized in a paper read in December last before the Geological Society (see Quart. Journ. Geol. Soc. vol xxviii. p. 46).

Dr. Anton Dohrn, without (as I think) any very clear reason, proposes to separate the Xiphosura and the Eurypterida, and also the Trilobita, from the Crustacea, on the ground that they do not, so far as we are at present aware, pass through a Nauplius stage; but the young are like the parents save in the fewer number of their somites. He is, however, unprepared to say they are Arachnids, so that he can only place them in a group intermediate between the Arachnida and Crustacea (the Gigantostraka of Hackel). Against this course I have protested on the grounds that if we take away the Trilobita from the pedigree of the Crustacea, one of the main arguments in favour of evolution to be derived from this class, so far from being strengthened, is destroyed. From what are the Crustacea of to-day derived? Are we to assume that they are all descended from the Phyllopods and Ostracods, the only two remaining orders whose life-history is conterminous with that of the Trilobita? Or are we to assume that the Arachnida are the older class? "If," as Fritz Müller well observes, "all the classes of the Arthropoda (Crustacea, Insecta, Myriopoda, and Arachnida) are indeed all branches of a common stem (and of this there can scarcely be a doubt), it is evident that the water-inhabiting and water-breathing Crustacea must be regarded as the original stem from which the other (terrestrial) classes, with their tracheal respiration, have branched off." (Facts and Arguments for Darwin, p. 120.)

* Under the name of *Goniocypoda Edwardsii*, I described a *true* Eocene shore-crab from the Red Marl of the Plastic Clay, High Cliff, Hampshire, in December 1867 (see Geol. Mag. vol. iv. p. 529, pl. 21. fig. 1).


RANGE AND EVOLUTION OF THE SEVERAL ORDERS OF CRUSTACEA IN TIME.
CRUSTACEA.
ARACHNIDA.
Laurentian.
Lower Cambrian.
Upper Cambrian.
Lower Silurian.
Upper Silurian.
Devonian.
Carboniferous.
Permian.
Triassic.
Jurassic.
Cretaceous.
Tertiary.
Recent.
Ostracoda
LEPADIDÆ
TURRILEPAS
Cirripedia
POLLICIPES
BALANIDÆ
Trilobita
Phyllopoda
Isopoda
PRÆARCTURUS
Stomapoda
URONECTES PYGOCEPHALUS
Decapoda-Macrura
ANTHRAPALÆMON
Decapoda-Anomoura
Decapoda-Brachyura
NEOLIMULUS
Merostomata-Xiphosura
BELLINURUS
PRESTWICHIA
LIMULUS
LIMULUS
Hemiaspis
Eurypterida
Pterygotus
LIMIT OF CLASS
EOSCORPIO
Scorpionidæ
Scorpio
Explanation of Lines.
Aberrant and parasitic types.
Groups which possessed both persistence and powers of modification and development.
Persistent types with little or no variation.
Groups which have died out.
Probable common point of ancestral divergence.

The accompanying Table (p. 326) is merely intended as an attempt roughly to indicate (according to our present knowledge of the earliest appearance in time of the several orders of Crustacea) the most probable manner in which the various groups were evolved from a common pre-Cambrian parent-stock. I have specially distinguished those which are merely persistent types, but incapable of modification, from those which were capable both of persistence and modification; and these again from the inadaptive types which have died out. The aberrant and highly specialized parasitic types appear last in time, and mark the culminating point of the Crustacea when conditions prevailed more highly favourable to the class than at any earlier period.

Report of the Committee appointed to organize an Expedition for observing the Solar Eclipse of Dec. 12, 1871.

At their Meeting in Edinburgh in August last, the General Committee of the British Association for the Advancement of Science having had under their consideration the great importance of observing the eclipse of 12th of December, 1871, authorized their President, Sir W. Thomson, F.R.S., to bring the matter to the notice of the Treasury, which he did in a letter dated 9th August, 1871, stating fully how desirable it was in the interest of science that advantage should be taken of this opportunity to advance solar physics, and explaining in general terms the best methods of carrying them out.

It was suggested in the President's letter that Mr. J. Norman Lockyer, F.R.S., who had long devoted himself to spectroscopic investigations, should form a member of the expedition.

The President was authorized by Sir E. Sabine, K.C.B., President of the Royal Society, and Mr. Lassell, President of the Royal Astronomical Society, to state to the Treasury their cordial concurrence in the request of the British Association.

A most prompt reply was received to their communication, the Treasury, by a letter dated 16th August, 1871, acceding at once to the request of the President, and granting a sum not exceeding £2000 for the purpose.

In the hope of a favourable reply being received from the Treasury, the General Committee had, by a resolution at their last Meeting in Edinburgh, authorized the General Officers to take such steps as they might deem advisable as soon as possible after the receipt of the Treasury letter. The General Officers held a meeting on the 22nd of August; and having in the first instance requested Mr. Norman Lockyer, F.R.S., to join them in consultation, they resolved to appoint a Committee to direct all the necessary arrangements.

To this Committee, as originally constituted, additional members were from time to time added. It now consists of the following names:—The President and General Officers of the Association, Prof. J. C. Adams, Sir G. B. Airy (Astronomer Royal), Prof. Clifton, Mr. De La Rue, Dr. Frankland, Mr. Hind, Mr. Lassell (President R.A.S.), Lord Lindsay, Mr. Lockyer, General Sabine, General Strachey, Colonel Strange, and Prof. Stokes.

The Treasury having been good enough to address the Admiralty and the War Office requesting their cooperation, the Committee entered into com-

munication with these departments and with the Colonial and Indian Officers, and have much pleasure in stating that they have had the most liberal and hearty assistance from all the departments of Government.

The first duty of the Committee was to arrange for the dispatch of instruments and instructions to Australia, which it was necessary to do by the mail of the 2nd of October.

By Mr. Lockyer's exertions, and the kindness of Mr. Huggins in making over a camera of Mr. Dallmeyer's, which the Committee undertook to replace within a month, these instruments were all sent off in good time, and reached Melbourne with little or no damage.

The unfortunate result of the expedition to Australia, from bad weather, is well known and deeply regretted, and need only be briefly mentioned.

The Committee now turned their attention to the selection of the places best adapted to observation in India. Very careful inquiries were made from every available source as to the nature of the climate in different parts of India on the 12th of December, and in these the Committee received most valuable assistance from General Strachey.

The season was about the middle of the north-east monsoon, making it probable that there would be fine weather on the west coast of the peninsula, but that the weather on the east coast and in Ceylon could not be depended upon, the rainy season breaking up in December, but sometimes early in the month, but at other times not till nearly or quite the end.

It was originally intended to fix the number of observers at five; but on further consideration it appeared to the Committee that, because of this uncertainty of weather, it was desirable to divide the expedition into as many parties as possible; with the very important assistance mentioned in the next paragraphs, they were of opinion that it would be feasible, by means of the Treasury grant, to purchase the necessary instruments and to provide passage-money for ten observers.

The Peninsular and Oriental Company, at the request of the Committee, made the most liberal arrangements for freight and passage to and from Point de Galle, and the Admiralty at once communicated by telegraph with Admiral Cockburn, at Trincomalee, receiving an immediate reply, stating the frigate 'Glasgow' would be at Galle on the 25th of November in readiness to transport the party to the place of observation and bring them back again.

The Governor of Ceylon, in the same liberal manner, not only placed the steamer 'Serendib' at the disposal of the expedition, but undertook to give all possible assistance in officers and material which might be needed.

After making these arrangements, the Committee appointed Mr. Lockyer chief of the expedition, and Dr. T. Thomson Secretary and Treasurer.

The selection of observers was necessarily difficult. To many highly qualified physicists the length of the voyage was an insuperable obstacle; but Mr. Lockyer was able to submit to the Committee the following names:—

1. Rev. R. Abbay, Wadham College, Oxford; 2. H. Davis, Esq.; 3. R. J. Friswell, Esq.; 4. Henry Holiday, Esq.; 5. W. Lewis, Esq.; 6. Captain Maclear, R.N.; 7. H. N. Moseley, Esq.; 8. Captain Tupman, R.M.A.—all gentlemen devoted to and well skilled in solar physics.

To the chief of the expedition and to these gentlemen the Committee have great pleasure in giving their most cordial thanks for the zeal which led them to undertake a long voyage with the sole object of the advancement of science, and in expressing their great satisfaction with the way in which the expedition was carried out.

Mr. Davis, the accomplished photographer of Lord Lindsay, undertook the

department of Photography; and the Committee have to express their sense of the generous assistance afforded them by that nobleman in supplying all the necessary photographic apparatus.

Mr. Holiday, a skilful artist, who had long been a student of physical science, undertook to sketch the phenomena of the eclipse.

To the other gentlemen the spectroscopic and polariscopic observations were allotted under the direction of Mr. Lockyer.

Before leaving England Mr. Lockyer telegraphed and wrote to Signor Respighi, a very eminent Italian astronomer, requesting him to join the party, which, by the liberality of the Italian Government, he was able to do, joining at Suez, and rendering most valuable assistance.

Mr. Lockyer tried further to obtain the assistance of several very distinguished foreign observers. He communicated with Mr. Young, M. Janssen, M. Zöllner, M. Ångström, Prof. Schmidt, and Mr. Peise; but from various causes none of these gentlemen could join the party.

The expedition embarked at Southampton on the steamer 'Mirzapore,' receiving early attention and assistance from Captain Paris, R.N.R., and the officers of that ship, which was selected on account of its passing through the Suez Canal, so that all risk of injury to the instruments was avoided. The party reached Galle on the 27th of November, fifteen days before the day of the eclipse.

Subject to any alteration which might become needful on the receipt of more complete information in Ceylon, Mr. Lockyer had made the following arrangements of stations and observers:—

Ceylon. Trincomalee: Mr. Moseley.
Jaffna: Mr. Lewis, Captain Tupman, R.M.A.

India. Poodoocotta, near Trichinopoly: Signor Respighi, Mr. Holiday.
Mannatoddy, in Wynaad: Rev. Mr. Abbay, Mr. Friswell.
Baikul, in Canara: Mr. Lockyer, Mr. Davis, Captain Maclear, Dr. Thomson.

The Ceylon party embarked at once on the 'Serendib,' where they were received by Captain Fyers, R.E., the Surveyor-General of Ceylon, and Captain Hogg, R.E., who had been requested by the Ceylon Government to assist the expedition, and both of whom furnished very valuable reports.

The other parties embarked on board the frigate 'Glasgow,' whence the Poodoocotta party was landed at Beypore, the Wynaad party at Cannanore, and the Canara party at Baikul.

The Committee are happy to state that the weather was favourable, and the observations successful at all the stations but one. At Mannatoddy, in Wynaad, the sun was obscured, and the regret with which the Committee learned the bad luck of Messrs. Abbay and Friswell was enhanced by their knowledge that the land journey of these observers was one of great hardship and fatigue.

The Committee are most anxious to take this opportunity of stating that the expedition received every possible assistance from the Viceroy and Governor-General, the late Lord Mayo, from the Governor of Madras, Lord Napier, and from the Governor of Ceylon, Sir Hercules Robinson, and from all the officials of both the Indian and Colonial Governments with whom they came in contact.

They have further to report that the frigate 'Glasgow' not having been able, owing to its services being urgently required elsewhere, to bring the parties back to Galle and Bombay, the Government of Madras was good enough to assist the expedition, which would otherwise have been in diffi-

culties as to travelling expenses from the places of observation to Galle or Bombay, by a liberal grant of £100.

In conclusion the Committee have much pleasure in laying before Section A an interim report by Mr. Lockyer on the results of the expedition, to be followed as soon as possible by the full report, which the Royal Astronomical Society have undertaken to publish.

An interim Report on the Results obtained by the British-Association Eclipse Expedition of 1871. *By* J. Norman Lockyer, *F.R.S.*

I. New Instruments.

These were as follows:—

1. A train of five prisms to view the corona.
2. A large prism of small angle placed before the object-glass of a telescope.

On these instruments I may remark that the Royal Astronomical Society, in the first instance, invited me to take charge of an Expedition to India merely to conduct spectroscopic observations; but although this request did me infinite honour, I declined it, because the spectroscope alone, as it had been used before, was, in my opinion, not competent to deal with all the questions now under discussion. Thus some of the most eminent American observers had come to the conclusion that the spectrum of hydrogen observed in the last eclipse round the sun, to a height of 8′, was a spectrum of hydrogen "far above any possible hydrogen" at the sun. Hence it was in some way reflected. Now with our ordinary spectroscopic methods it was extremely difficult, and one might say impossible, to determine whether the light which the spectroscope analyzed was really reflected or not; and that was the whole question.

It became necessary, therefore, in order to give any approach to hopefulness, to proceed in a somewhat different way in the 1871 expedition, with regard to the spectroscope, and, to guard against failure, to supplement such observations with photographs.

To understand the method adopted, let us suppose a train of prisms. Take one prism out of the train, and consider what will happen if we illuminate a slit with a monochromatic light and observe it through the prism. If we render sodium vapour incandescent and illuminate the slit by means of it, we get a bright yellow image of the slit, due to the vapour of the metallic sodium only giving us yellow light. But why is it that we get a line? Because we employ a line slit. If, instead of a straight line, we have a crooked line for the slit, then we see a crooked line through the prism. Going one step further: suppose that instead of a line, whether straight or crooked, we have a slit in the shape of a ring, we see a ring image through the prism. And then comes this point: if, when we work in the laboratory, we examine these various slits, illuminated by these various vapours, if we observe the corona in the same way, we shall get a ring built up by each ray of light which the corona gives to us, since we know, from the American observations, that there were bright lines in the spectrum of the corona as observed by a line slit; in other words, the corona examined by means of a long train of prisms should give us an image of itself painted by each ray which the corona is competent to radiate towards us*.

These were the considerations which led to the adoption of this new attempt to investigate the nature of the corona now in question. It was, to use a

* After I had thought of this arrangement, and had secured an instrument to carry it out, Prof. Young, in a communication to 'Nature,' suggested the same method of observation.

train of prisms, pure and simple, using the corona as the slit, a large number of prisms being necessary to separate the various rings we hoped to see, by reason of their strong dispersion.

This principle, good for a train of prisms such as I have referred to, is good also for a single prism in front of the object-glass of a telescope. Such was the method adopted by Prof. Respighi, the distinguished Director of the Observatory of the Capitol of Rome, who accompanied the expedition.

This method, if it succeeded, would be superior to the ordinary one in this way. If we were dealing merely with scattered light, then all the rings formed by vapours of equal brilliancy at the base of the chromosphere would be of the same height; while if such scattering were not at work, the rings would vary according to the actual height of the vapours in the sun's atmosphere.

3. Integrating spectroscopes *driven by clockwork*.

4. A self-registering integrating spectroscope, furnished with telescopes and collimators of large aperture and large prisms. (This instrument was lent by Lord Lindsay.)

5. A polariscope-telescope so arranged that the same observer could almost simultaneously observe both with the Savart and the Biquartz.

6. A polariscope-telescope arranged for rapid sweeping round the corona at a given distance from moon's limb.

II. The Main Results.

Spectroscopic Observations.

It has been established that the idea that we do not get hydrogen above 10″ above the sun is erroneous, for we obtained evidence that hydrogen exists to a height of 8′ or 10′ at least above the sun.

Just as the sun disappeared Prof. Respighi employed the instrument to which I have already referred to determine the materials of which the prominences which were then being eclipsed were composed; and he got the prominences shaped out in red, yellow, and in violet light, a background of impure spectrum filling the field; and then as the moon swept over those prominences they became invisible. He saw the impure spectrum and the yellow and violet rings gradually die out, and then three broad rings, painted in red. green, and blue, gradually form in the field of view of his instrument; and as long as the more brilliant prominences on both sides of the sun were invisible he saw these magnificent rings.

These rings were formed by C and F, which show us that hydrogen extends at least 7′ high; for had we been dealing with mere glare, *had we not been dealing with hydrogen itself, we should have got a yellow ring as well.* In addition to the red ring and the blue and violet, which indicate the spectrum of hydrogen, he saw a bright green ring, much more brilliant than the others due to 1474.

While Prof. Respighi was observing these rings by means of a single prism and a telescope of some 4 inches aperture, some 300 miles away from him (he was at Poodocottah and I was at Bekul) I had arranged the train of five prisms. My observation was made intermediately, as it were, between the two observations of Prof. Respighi's. The observations may be thus compared:—

Respighi ..	C D^3		F G	....	Prominence at beginning of eclipse.
Lockyer ..	C	1474	F G	....	Corona 80″ after beginning of totality.
Respighi ..	C	1474	F	....	Corona mid eclipse.

I had no object-glass to collect light, but I had more prisms to disperse it, so that with me the rings were not so high as those observed by Respighi, because I had not so much light to work with; but, such as they were, I saw them better, because the continuous spectrum was more dispersed, and the rings (the images of the corona) therefore did not overlap. Hence doubtless Respighi missed the violet ring which I saw; but both that and 1474 were very dim, while C shot out with marvellous brilliancy, and D^3 was absent.

These observations thus tend to show, therefore, that instead of the element the line of which corresponds with 1474 existing alone just above the prominences, the hydrogen accompanies it to what may be termed a great height above the more intensely heated lower levels of the chromosphere, including the prominences, in which the lower vapours are thrown to a greater height. With a spectroscope of small dispersion attached to the largest mirror of smallest focus which I could obtain in England, the gaseous nature of the spectrum, as indicated by its *structure* (that is, bands of light and darker intervals as distinguished from a continuous spectrum properly so called), was also rendered evident.

Photographs and Structure of Corona.

The photographic operations (part of the expense of which was borne by Lord Lindsay) were most satisfactory, and the solar corona was photographed to a greater height than it was observed by the spectroscope, and with details which were not observed in the spectroscope. Mr. Davis was fortunate enough to obtain five photographs of great perfection at Bekul, and Captain Hogg obtained some at Jaffna; but the latter lack in detail. The solar nature of most, if not all, of the corona recorded on the plates is established by the fact that the plates, taken in different places, and both at the beginning and end of totality, closely resemble each other; and much of the exterior detailed structure is a continuation of that observed in the inner portion, independently determined by the spectroscope to belong to the sun.

This structure I was also enabled to observe in my $6\frac{1}{4}$-inch equatorial, even three minutes after totality was over; and we may now say that we know all about the corona, so far as the structure of its lower brighter levels (that portion, namely, which time out of mind has been observed both before and after totality) is concerned. It may be defined as consisting of cool prominences—that is to say, in this region of the corona we will find the same appearances as in prominences, minus the brightness. We find the delicate thread-like filaments which all are now so familiar with in prominences; the cloudy light masses, the mottling, the nebulous structure, all are absolutely produced in the corona; and I may add that the fainter portion of the ring, some 5′ round the sun, reminded me forcibly in parts of the nebula of Orion and that surrounding η Argus, as depicted by Sir John Herschel in his Cape observations.

While both in the prism and the $6\frac{1}{4}$-inch equatorial the corona seemed to form pretty regular rings round the dark moon, of different heights, according to the amount of light utilized by the instrument, on the photographic plates the corona (which, as I have before stated, exceeds the limits actually seen in the instrument I have named) has very irregular (*ignored by the spectroscope*), somewhat stellate poles—a fact perhaps connected with the other fact, that the most active and most brilliant prominences rarely occur there.

Sketches.

From the photographs, in which the corona is depicted actinically, we pass to the drawings, in which it is depicted visually. I would first call attention to two drawings made by Mr. Holiday, who formed part of the expedition, and in whose eye every one who knows him will have every confidence.

First, there is a drawing made at the commencement of the totality, and then a drawing made at the end. There is a wonderful difference between these drawings; the corona is in them much more extensive than it is represented actinically on our plates.

In another drawing, made by Captain Tupman, we have something absolutely different from the photographs and from Mr. Holiday's sketches, inasmuch as we get an infinite number of dark lines and a greater extension than in the photographs, though in the main the shape of the actinic corona is shown.

The corona, as it appeared to me, was nothing but an assemblage of such bright and dark lines; it lacked all the structure of the photographs, and appeared larger; and I have asked myself whether these lines do not in some way depend on the size of the telescope or the absence of a telescope. It seems as if observations of the corona with the naked eye, or with a telescope of small power, may give us such lines; but that when we use a telescope of large power it will give, close to the moon, the structure to which I have referred, and abolish the exterior structure altogether, leaving a ring round the dark body of the moon, such as Prof. Respighi and myself saw in our trains of prisms, and I in the $6\frac{1}{4}$-inch telescope, in which the light was reduced by high magnification so as to bring the corona to a definite ring some 5′ high, while Prof. Respighi, using a 4-inch telescope, brought the corona down to a ring something like 7′ high.

Many instances of changing rays, like those seen by Plantamour in 1860, were recorded by observers in whom I have every confidence, one observer noting that the rays revolved and disappeared over the rifts.

Polariscopic Observations.

Mr. Lewis, in sweeping round the corona at a distance of some 6′ or 7′ from the sun's limb, using a pair of compensating quartz wedges as an analyzer, which remained parallel to itself when the telescope swept round, observed the bands gradually to change in intensity, then disappear, bands of a complementary character afterwards appearing, thereby indicating radial polarization.

Dr. Thomson, at Bekul, saw strong traces of atmospheric, but none of radial polarization, with a Savart. With the same class of instrument the result obtained by myself was precisely similar; while on turning in the Biquartz, at the top and bottom of the image of the corona, *i. e.* near the sun's equator, faint traces of radial polarization were perceptible for a short distance from the moon's limb. Captain Tupman, who observed with the polariscope after totality, announces strong radial polarization extending to a very considerable distance from the dark moon.

Reversal of Lines at beginning and end of Totality.

Captain Maclear, who was observing with me at Bekul for some time just before the commencement of totality, but when the light of our atmosphere was cut off by the interposition of the dark moon, saw a large number of very fine lines of different heights at the base of the chromosphere.

Mr. Pringle, also at Bekul, saw many lines flash into the field of an analyzing spectroscope, carried by clockwork, at the end of totality.

Captain Fyers, the Surveyor-General of Ceylon, observing with an integrating spectroscope, saw something like a reversal of all the lines at the beginning, but nothing of the kind at the end.

Mr. Fergusson, observing with an instrument of the same kind, saw reversal neither at the beginning nor the end, though during totality he saw more lines than Captain Fyers.

Mr. Moseley states that at the beginning of the eclipse he did not see this reversal of lines. Whether it was visible at the end he could not tell, because at the close the slit had travelled off the edge of the moon.

Prof. Respighi, using no slit whatever, and being under the best conditions for seeing the reversal of the lines, certainly did not see it at the beginning; but he considers he saw it at the end, though about this he is doubtful.

From the foregoing general statement of the observations made on the eclipse of last year, it will be seen that knowledge has been very greatly advanced, and that most important data have been obtained to aid in the discussion of former observations. Further, many of the questions raised by the recent observations make it imperatively necessary that future eclipses should be carefully observed, as periodic changes in the corona may then possibly be found to occur. In these observations the instruments above described should be considered normal, and they should be added to as much as possible.

Preliminary Report of a Committee, consisting of Professor MICHAEL FOSTER, *F.R.S., Professor* W. H. FLOWER, *F.R.S., and* BENJAMIN LOWNE, *M.R.C.S., appointed for the purpose of making Terato-embryological Inquiries.*

MR. LOWNE reported on two forms of Incubators. He thought from his experiments that to insure success the heat must be applied above the egg, and that the death of all those which he placed in an incubator heated beneath was due to convection.

Death took place in all these cases from rupture of the yelk-vessels between the third and tenth day.

Other deficiencies were observed in many embryos; but owing to the imperfect condition of the incubators in use, Mr. Lowne was not sufficiently satisfied as to their nature.

Mr. Lowne believed he had adopted a plan of incubator, in which the temperature is regulated by an air-thermometer and the heat is applied above, which would enable him to arrive at satisfactory results in the course of next year.

Report on Recent Progress in Elliptic and Hyperelliptic Functions. *By* W. H. L. Russell, *F.R.S.*

We now enter on the consideration of the Hyperelliptic Functions. I propose to divide the subject into four parts, thus:—

Part I. On the System of Hyperelliptic Differential Equations adopted by Dr. Weierstrass.

Part II. On the System of Hyperelliptic Differential Equations adopted by Jacobi, Göpel, and Rosenhain.

Part III. On the Transformation of Hyperelliptic Functions.

I hope to add

Part IV. On certain Theorems not involving the Periods of the Functions, with a Supplement to the Report.

Part I. *On the System of Hyperelliptic Differential Equations adopted by Dr. Weierstrass.*

We now proceed to explain the discoveries of Dr. Weierstrass. It will be seen that the form of his hyperelliptic differential equations is different from that assumed by Jacobi, Göpel, and Rosenhain. The object of Weierstrass is to solve these equations; and the advantage of his method will be seen when we consider that he solves the hyperelliptic equations generally, and not for a particular case, which is all that Göpel and Rosenhain had previously effected. Weierstrass assumes as follows (Crelle, 47):—

$$u_1=\int_{a_1}^{x_1}\frac{P(x)}{x-a_1}\cdot\frac{dx}{2\sqrt{R(x)}}+\int_{a_3}^{x_2}\frac{P(x)}{x-a_1}\cdot\frac{dx}{2\sqrt{R(x)}}+\ldots+\int_{a_{2n-1}}^{x_n}\frac{P(x)}{x-a_1}\cdot\frac{dx}{2\sqrt{R(x)}},$$

$$u_2=\int_{a_1}^{x_1}\frac{P(x)}{x-a_3}\cdot\frac{dx}{2\sqrt{R(x)}}+\int_{a_3}^{x_2}\frac{P(x)}{x-a_3}\cdot\frac{dx}{2\sqrt{R(x)}}+\ldots+\int_{a_{2n-1}}^{x_n}\frac{P(x)}{x-a_3}\cdot\frac{dx}{2\sqrt{R(x)}},$$

&c.=&c.

$$=\int_{a_1}^{x_1}\frac{P(x)}{x-a_{2n-1}}\cdot\frac{dx}{2\sqrt{R(x)}}+\int_{a_3}^{x_2}\frac{P(x)}{x-a_{2n-1}}\cdot\frac{dx}{2\sqrt{R(x)}}+\ldots+\int_{a_{2n-1}}^{x_n}\frac{P(x)}{x-a_{2n-1}}\cdot\frac{dx}{2\sqrt{R(x)}},$$

where $R(x)=(x-a_0)(x-a_2)(x-a_4)\ldots(x-a_{2n}),$

$P(x)=(x-a_1)(x-a_3)\ldots(x-a_{2n-1})$;

and let $Q(x)=(x-a_0)(x-a_2)\ldots(x-a_{2n}),$

so that $R(x)=P(x).Q(x).$

If $L(x)=(x-x_1)(x-x_2)\ldots(x-x_n),$

we define

$$al(u_1u_2\ldots u_n)_\alpha=\frac{\sqrt{(-1)^{\bar{\alpha}}L(a_\alpha)}}{\sqrt[4]{(-1)^\alpha R'(a_\alpha)}},$$

where $\bar{\alpha}$ is the greatest number contained in $\frac{1}{2}\alpha$;

also
$$al(u_1u_2\ldots u_n)_{\alpha,\beta}=\sqrt{\pm(a_\alpha-a_\beta)}$$
$$al(u_1u_2\ldots u_n)_\alpha al(u_1u_2\ldots u_n)_\beta \Sigma\left\{\frac{\sqrt{\mathrm{R}(x_\nu)}}{(x_\nu-a_\alpha)(x_\nu-a_\beta)\mathrm{L}'(x_\nu)}\right\},$$
where the upper or lower sign is to be taken according as α is less or greater than β, and where Σ refers to ν, and $\nu=1, 2, 3\ldots n$.

Now let
$$\overset{\alpha}{\mathrm{K}}_\nu=\int_{a_\alpha}^{\infty}\frac{\mathrm{P}(x)dx}{2(x-a_{2\nu-1})\sqrt{\mathrm{R}(x)}};$$
then
$$\overset{0}{\mathrm{K}}_\nu-\overset{1}{\mathrm{K}}_\nu+\overset{2}{\mathrm{K}}_\nu-\ldots+\overset{2\nu}{\mathrm{K}}_\nu=0,$$
for $\nu=1, 2, 3\ldots n$. (See Jacobi, Crelle, 13.)

Moreover, let
$$\mathrm{K}_{\nu,c}=\overset{2c-1}{\mathrm{K}}_\nu-\overset{2c}{\mathrm{K}}_\nu=\int_{a_{2c-1}}^{a_{2c}}\frac{\mathrm{P}(x)dx}{2(x-a_{2\nu-1})\sqrt{\mathrm{R}(x)}},$$
$$i\overline{\mathrm{K}}_{\nu,c}=\overset{2c-2}{\mathrm{K}}_\nu-\overset{2c-1}{\mathrm{K}}_\nu=\int_{a_{2c-2}}^{a_{2c-1}}\frac{\mathrm{P}(x)dx}{2(x-a_{2\nu-1})\sqrt{\mathrm{R}(x)}};$$
then also we find
$$\overset{0}{\mathrm{K}}_\nu=\mathrm{K}_{\nu,1}+\mathrm{K}_{\nu,2}+\ldots\ \mathrm{K}_{\nu,n},$$
$$\overset{1}{\mathrm{K}}_\nu=\mathrm{K}_{\nu,1}+\mathrm{K}_{\nu,2}+\ldots\ \mathrm{K}_{\nu,n}-i\overline{\mathrm{K}}_{\nu,1},$$
$$\overset{2}{\mathrm{K}}_\nu=\mathrm{K}_{\nu,2}+\mathrm{K}_{\nu,3}+\ldots\ \mathrm{K}_{\nu,n}-i\overline{\mathrm{K}}_{\nu,1},$$
$$\overset{3}{\mathrm{K}}_\nu=\mathrm{K}_{\nu,2}+\ldots\quad+\mathrm{K}_{\nu,n}-i\overline{\mathrm{K}}_{\nu,1}-i\overline{\mathrm{K}}_{\nu,2},$$
$$\overset{4}{\mathrm{K}}_\nu=\mathrm{K}_{\nu,3}+\ldots\quad+\mathrm{K}_{\nu,n}-i\overline{\mathrm{K}}_{\nu,1}-i\overline{\mathrm{K}}_{\nu,2},$$
$$\ldots=\ldots$$
$$\overset{2n}{\mathrm{K}}_\nu=-i\overline{\mathrm{K}}_{\nu,1}-i\overline{\mathrm{K}}_{\nu,2}-\ldots-i\overline{\mathrm{K}}_{\nu,n};$$
then the following four fundamental formulæ hold good, where we make use of the symbol β/α to denote zero when α is less than β, and unity when α is greater than β:—
$$al(u_1+\overset{\alpha}{\mathrm{K}}_1\ldots)_\alpha=\frac{i^{\alpha-2\bar{\alpha}}}{al(u_1u_2\ldots)_\alpha}, \quad \ldots \quad (1)$$
$$al(u_1-\overset{\alpha}{\mathrm{K}}_1\ldots)_\alpha=\frac{i^{\alpha-2\bar{\alpha}}}{al(u_1u_2\ldots)_\alpha},$$
$$al(u_1+\overset{\beta}{\mathrm{K}}_1\ldots)_\alpha=\frac{i^{\beta/\alpha}al(u_1,u_2\ldots)_{\alpha,\beta}}{al(u_1\ldots)_\beta}, \quad \ldots \quad (2)$$
$$al(u_1-\overset{\beta}{\mathrm{K}}_1\ldots)_\alpha=\frac{-i^{\beta/\alpha}al(u_1\ldots)_{\alpha,\beta}}{al(u_1\ldots)_\beta}.$$

We shall now indicate the method by which these formulæ are to be proved; it will be sufficient if we put $n=3$, which will guide at once to the investigation for (n) greater than 3. Let

$$(x-a_1)(x-a_3)(x-a_5)(x-p)^2(x-q)^2(x-r)^2-$$
$$(x-a_0)(x-a_2)(x-a_4)(x-a_6)(c_0+c_1x+c_2x^2)^2=$$
$$(x-x_1')(x-x_2')(x-x_3')(x-x_1'')(x-x''_2)(x-x''_3)(x-x_1)(x-x_2)(x-x_3), \quad (3)$$

and put in this equation

$$x_1''=a_0,\ x_2''=a_2,\ x''_3=a_4,$$

which also necessitates

$$p=a_0,\ q=a_2,\ r=a_4,$$

and the equation becomes

$$(x-a_1)(x-a_3)(x-a_5)(x-a_0)(x-a_2)(x-a_4)-(x-a_6)(c_0+c_1x+c_2x^2)^2$$
$$=(x-x'_1)(x-x'_2)(x-x'_3)(x-x_1)(x-x_2)(x-x_3).\ .\quad .\quad .\quad .\quad . \quad (4)$$

Putting in this equation successively $x=x_1$, $x=x_2$, $x_3=x_2$, we have

$$c_0+c_1x_1+c_2x_1^2=\frac{\sqrt{Rx_1}}{x_1-a_6},$$

$$c_0+c_1x_2+c_2x_2^2=\frac{\sqrt{Rx_2}}{x_2-a_6},$$

$$c_0+c_1x_3+c_2x_3^2+\frac{\sqrt{Rx_3}}{x_3-a_6};$$

whence

$$c_0=\frac{\sqrt{Rx_1}}{x_1-a_6}\cdot\frac{x_2x_3}{(x_2-x_1)(x_3-x_1)}$$
$$+\frac{\sqrt{Rx_2}}{x_2-a_6}\cdot\frac{x_1x_3}{(x_1-x_2)(x_3-x_2)}+\frac{\sqrt{Rx_3}}{x_3-a_6}\cdot\frac{x_1x_2}{(x_2-x_3)(x_1-x_3)},$$

$$c_1=-\frac{\sqrt{Rx_1}}{x_1-a_6}\cdot\frac{x_2+x_3}{(x_2-x_1)(x_3-x_1)}$$
$$-\frac{\sqrt{Rx_2}}{x_2-a_6}\cdot\frac{x_1+x_3}{(x_1-x_2)(x_3-x_2)}-\frac{\sqrt{Rx_3}}{x_3-a_6}\cdot\frac{x_1+x_2}{(x_2-x_3)(x_1-x_3)},$$

$$c_2=\frac{\sqrt{Rx_1}}{x_1-a_6}\cdot\frac{1}{(x_2-x_1)(x_3-x_1)}+\frac{\sqrt{Rx_2}}{x_2-a_6}\cdot\frac{1}{(x_1-x_2)(x_3-x_2)}$$
$$+\frac{\sqrt{Rx_3}}{x_3-a_6}\cdot\frac{1}{(x_1-x_3)(x_2-x_3)}.$$

Substitute these values in equation (4), and we have, putting at the same time $x=a_1$,

$$\sqrt{\{(a_1-x'_1)(a_1-x'_2)(a_1-x'_3)\}}\sqrt{\{(a_1-x_1)(a_1-x_2)(a_1-x_3)\}}$$
$$=\pm i\sqrt{a_1-a_6}\left\{\frac{\sqrt{Rx_1}}{x_1-a_6}\cdot\frac{(a_1-x_2)(a_1-x_3)}{(x_2-x_1)(x_3-x_1)}\right.$$

$$+\frac{\sqrt{Rx_2}}{x_2-a_6}\cdot\frac{(a_1-x_1)(a_1-x_3)}{(x_1-x_2)(x_3-x_2)}+\frac{\sqrt{Rx_3}}{x_3-a_6}\cdot\frac{(a_1-x_1)(a_1-x_2)}{(x_1-x_3)(x_2-x_3)}\Bigg\}.$$

Hence also

$$\sqrt{\{(a_1-x'_1)(a_1-x'_2)(a_1-x'_3)\}}=\pm i\sqrt{a_1-a_4}\sqrt{\{(a_1-x_1)(a_1-x_2)(a_1-x_3)\}}$$
$$\left\{\frac{\sqrt{Rx_1}}{(x_1-a_6)(x_1-a_1)L'_1x_1}+\frac{\sqrt{Rx_2}}{(x_2-a_6)(x_2-a_1)L'x_2}+\frac{\sqrt{Rx_3}}{(x_3-a_6)(x_3-a_1)L'x_3}\right\}. \quad (5)$$

It only remains to determine the value of $\sqrt{\{(a_1-x'_1)(a_1-x'_2)(a_1-x'_3)\}}$. For this purpose, let u'_1, u'_2, u'_3 be what u_1, u_2, u_3 become when we substitute x'_1, x'_2, x'_3 for x_1, x_2, x_3.

Hence we have from Abel's theorem, applied to equation (3), ($\epsilon_\mu=\pm 1$),

$$\epsilon_1\int_{a_1}^{x'_1}\frac{Px}{x-a_1}\cdot\frac{dx}{2\sqrt{Rx}}+\epsilon_2\int_{a_3}^{x'_2}\frac{Px}{x-a_1}\cdot\frac{dx}{2\sqrt{Rx}}+\epsilon_3\int_{a_5}^{x'_3}\frac{P(x)}{x-a_1}\cdot\frac{dx}{2\sqrt{Rx}}$$
$$+\epsilon_4\int_{a_1}^{a_6}\frac{Px}{x-a_1}\cdot\frac{dx}{2\sqrt{Rx}}+\epsilon_5\int_{a_3}^{a_2}\frac{Px}{x-a_1}\cdot\frac{dx}{2\sqrt{Rx}}+\epsilon_6\int_{a_5}^{a_4}\frac{Px}{x-a_1}\cdot\frac{dx}{2\sqrt{Rx}}$$
$$+\epsilon_7\int_{a_1}^{x_1}\frac{Px}{x-a_1}\cdot\frac{dx}{2\sqrt{Rx}}+\epsilon_8\int_{a_3}^{x_2}\frac{Px}{x-a_1}\cdot\frac{dx}{2\sqrt{Rx}}+\epsilon_9\int_{a_5}^{x_3}\frac{Px}{x-a_1}\cdot\frac{dx}{2\sqrt{Rx}}$$

$=0$. From this it follows that $u'_1=u_1+\overset{6}{K}_1$; and therefore

$$al(u'_1\ldots.)_1=al(u_1+\overset{6}{K}_1,\ \ldots.)_1. \quad \ldots\ldots \quad (6)$$

Now $al(u'_1\ldots.)_1$ differs only by a constant factor from

$$\sqrt{(a_1-x')(a_1-x'_2)(a_1-x'_3)}\,;$$

hence, comparing (5) and (6), we perceive the truth of (4), where $\alpha=1$ and $\beta=6$. It is easy from this to see that (2) must be generally true, when we give $\overset{\beta}{K}_1$ the positive sign. If we give $\overset{\beta}{K}_1$ the negative sign, we must change the signs of ϵ_4, ϵ_5, ϵ_6, &c. in the equation derived from Abel's theorem; but this may also be effected by changing the sign of $\sqrt{R(x)}$ in the second line of that equation, and therefore the signs of $\sqrt{Rx_1}$, $\sqrt{Rx_2}$, $\sqrt{Rx_3}$ in (5); hence $al\,(u_1+\overset{\beta}{K}_1\ \ldots)$, $al(u_1-\overset{\beta}{K}_1)$ are equal, but have opposite signs. But now put in equation (3)

$$x''_1=a_2,\ x''_2=a_4,\ x''_1=a_6,$$

then

$$(x-a_1)(x-a_3)(x-a_5)(x-a_2)(x-a_4)(x-a_6)-(x-a_0)(c_0+c_1x+c_2x^2)^2$$
$$=(x-x'_1)(x-x'_2)(x-x'_3)(x-x_1)(x-x_2)(x-x_3):$$

hence, putting $x=a_0$, we see that

$$\sqrt{(a_0-x'_1)(a_0-x'_2)(a_0-x'_3)}\sqrt{(a_0-x_1)(a_0-x_2)(a_0-x_3)}$$

is constant, or

$$al(u_1+\overset{0}{K}_1\ldots\ldots)_0 al(u_1\ldots\ldots)_0$$

is constant, applying Abel's theorem as before. Hence we see the truth of equation (1).

Section 2.—Hence it easily follows that

$$al(u_1+2\overset{\alpha}{K}_1\ldots\ldots)_\alpha=+al(u_1\ldots\ldots)_\alpha,$$

$$al(u_1+2\overset{\beta}{K}_1\ldots\ldots)_\alpha=-al(u_1\ldots\ldots)_\alpha,$$

the last formula of course holding good when β and α are unequal.

Hence, if

$$K_\nu=\mu_0\overset{0}{K}+\mu_1\overset{1}{K}_\nu+\ldots\ldots\mu_{2n}\overset{2n}{K}_\nu,$$

and

$$\mu=\mu_0+\mu_1+\ldots\ldots+\mu_{2n},$$

where μ_0, $\mu_1\ldots\ldots$ are any whole numbers, then

$$al(u_1+2K_1\ldots\ldots)_\alpha=(-1)^{\mu-\mu_\alpha}al(u_1\ldots\ldots)_\alpha.$$

Also let

$$K'_{\nu,c}=\overline{K}_{\nu,1}+\overline{K}_{\nu,2}+\ldots\ldots\overline{K}_{\nu,c},$$

and

$$\omega_\nu=m_1K_{\nu,1}+m_2K_{\nu,2}+\ldots\ldots+m_nK_{\nu,n},$$

$$\omega'_\nu=m'_1K'_{\nu,1}+m'_2K'_{\nu,2}+\ldots\ldots+m'_nK'_{\nu,n},$$

where m_1, $m_2\ldots\ldots m'_1$, m'_2 are any whole numbers; then we find the two following formulæ:

$$al(u_1+2\omega_1\ldots\ldots)_\alpha=(-1)^{m_\alpha-\bar{\alpha}}al(u_1\ldots\ldots)_\alpha,$$

where, when $\alpha=0_1$, m_0 must be taken as zero, and

$$al(u_1+2\omega'_1i\ldots\ldots)_\alpha=(-1)^{m'_n+m'_{n-1}+\ldots\ldots m_{\bar{\alpha}+1}}al(u_1\ldots\ldots)_\alpha,$$

in which formula, when $\alpha=2n$, the multiplier of $al(u_1\ldots\ldots)_{2n}$ is to be taken as unity.

Section 3.—Let

$$\alpha\lambda(u_1,u_2\ldots\ldots u_n)=\sum_1^n{}_\nu\frac{1}{2}\cdot\frac{\sqrt{Ra}}{Pa}\cdot\int_{a_{2\nu-1}}^{x_\nu}\frac{Px}{x-a}\cdot\frac{dx}{\sqrt{Rx}},\quad\ldots\quad(1)$$

$$d.\alpha\lambda(u_1,u_2\ldots\ldots u_n)_c=\sum_1^n{}_\nu\left\{\frac{1}{2}\cdot\frac{Q(a_{2c-1})}{P'(a_{2c-1})}\cdot\frac{Px_\nu dx_\nu}{(x_\nu-a_{2c-1})^2\sqrt{Rx_\nu}}\right\},\quad.\quad(2)$$

which last formula may be written thus:

$$d.\alpha\lambda(u_1u_2\ldots\ldots)_c=\frac{e^2_{2c-1}du_c}{al^2(u_1\ldots)_{2c-1}}+\sum_1^n{}'_\nu\left\{\frac{e^2_{2c-1}e^2_{2\nu-1}al^2(u_1\ldots)_{2\nu-1}(du_c-du_\nu)}{(a_{2c-1}-a_{2\nu-1})al^2(u_1u_2\ldots)_{2c-1}}\right\}.\quad.\quad(3)$$

In this expression the value (c) is excluded from those we successively give to ν.

To prove this last formula I refer the reader to a formula proved by Weierstrass at the end of the first chapter of his memoir in the 52nd volume of Crelle's Journal. Making use of a formula which will be found at p. 312 of the same volume, he gives

$$\Sigma\frac{1}{2}\frac{\mathrm{P}x_\alpha}{x_\alpha-a}\cdot\frac{dx_\alpha}{\sqrt{\mathrm{R}x_\alpha}}=\frac{\Sigma\left\{-\frac{\mathrm{Q}a_\alpha}{\mathrm{P}'a_\alpha}\cdot\frac{al^2(u_1\,.\,.)_\alpha du_\alpha}{a-a_\alpha}\right\}}{1-\Sigma\left\{\frac{\mathrm{Q}a_\alpha}{\mathrm{P}'a_\alpha}\cdot\frac{al^2(u_1\,.\,.)_\alpha}{a-a_\alpha}\right\}}.$$

Now substitute in the first member of this equation $(x_\alpha-a_\beta)-(a-a_\beta)$ for $x_\alpha-a$, and in the second member $(a-a_\beta)-(a_\alpha-a_\beta)$ for $a-a_\alpha$, expand both members in terms of $a-a_\beta$, and equate the coefficients of the first power of $a-a_\beta$ on both sides of the expression thus developed, and we have an equation of the form

$$\Sigma\frac{1}{2}\cdot\frac{\mathrm{P}x_\alpha}{(x_\alpha-a_\beta)^2}\,\frac{dx_\alpha}{\sqrt{\mathrm{R}x_\alpha}}=\frac{1}{q_\beta}\cdot\frac{du_\beta}{al^2(u_1\,.\,.)_\beta}+\Sigma'\frac{q_\alpha}{q_\beta}\frac{al^2(u_1u_2\ldots.u_n)_\alpha(du_\beta-du_\alpha)}{(a_\beta-a_\alpha)al^2(u_1u_2\ldots.u_n)_\beta},$$

where Σ' applies to α, the value β being excluded from the values of α thus arising, and q_α, q_β certain constants depending respectively on a_α and a_β. Allowing for the different notation, this formula is equivalent to the equation we wish to prove.

Section 4.—Differentiating equation (3) of last section, we have

$$\frac{d\,.\,\alpha\lambda(u_1u_2\ldots.)_c}{du_\nu}=-\frac{e^2_{2c-1}e^2_{2\nu-1}}{a_{2c-1}-a_{2\nu-1}}\cdot\frac{al^2(u_1\ldots.)_{2\nu-1}}{al^2(u_1\ldots.)_{2c-1}}.$$

From this we deduce, by applying formulæ (1) and (2) of the first section,

$$\frac{d}{du_\alpha}\alpha\lambda(u_1-\overset{2\nu-1}{\mathrm{K}_1}\ldots.)_\nu=\frac{d}{du_\nu}\alpha\lambda(u_1-\overset{2\alpha-1}{\mathrm{K}_1}\ldots.)_\alpha.\quad\ldots\quad(\mathrm{A})$$

We next put

$$\overset{a}{\mathrm{J}}_\nu=\int_{a_\alpha}^{\infty}\frac{1}{2}\cdot\frac{\mathrm{Q}(a_{2\nu-1})}{\mathrm{P}'(a_{2\nu-1})}\cdot\frac{\mathrm{P}(x)}{(x-a_{2\nu-1})^2}\cdot\frac{dx}{\sqrt{\mathrm{R}(x)}},$$

and also

$$\mathrm{J}_{\nu,\,c}=\overset{2c-1}{\mathrm{J}_\nu}-\overset{2c}{\mathrm{J}}_{\nu,\,c},\quad i\bar{\mathrm{J}}_{\nu,\,c}=\overset{2c-2}{\mathrm{J}_\nu}-\overset{2c-1}{\mathrm{J}}_\nu,$$

$$\mathrm{J}'_{\nu,c}=\bar{\mathrm{J}}_{\nu,\,1}+\bar{\mathrm{J}}_{\nu,\,2}+\ldots.+\bar{\mathrm{J}}_{\nu,\,c};$$

then the following equation is given connecting the new transcendents:

$$\frac{d\log_e al(u_1,u_2\ldots.)_\alpha}{du_\nu}=\overset{\alpha}{\mathrm{J}}_\nu-\alpha\lambda(u_1+\overset{\alpha}{\mathrm{K}_1}-\overset{2\nu-1}{\mathrm{K}_1}\ldots.)_\nu+\alpha\lambda(u_1-\overset{2\nu-1}{\mathrm{K}_1}\ldots.)_\nu.\quad(1)$$

If we write it

$$\frac{d\log_e al(u_1u_2\ldots.)_{2a-1}}{dv_\nu}=\overset{2a-1}{\mathrm{J}}_\nu-\alpha\lambda(u_1+\overset{2a-1}{\mathrm{K}_1}-\overset{2\nu-1}{\mathrm{K}_1}\ldots.)_\nu+\alpha\lambda(u_1-\overset{2\nu-1}{\mathrm{K}_1}\ldots.)_\nu.$$

and differentiate, we shall have

$$\frac{d^2 \log_\epsilon al(u_1, u_2 \ldots .)_{2\alpha-1}}{du_\alpha du_\nu} = -\frac{d}{du_\alpha} \alpha\lambda(u_1 + \overset{2\alpha-1}{\mathrm{K}_1} - \overset{2\nu-1}{\mathrm{K}_1} \ldots .)_\nu + \frac{d}{du_\alpha} \alpha\lambda(u_1 - \overset{2\nu-1}{\mathrm{K}_1} \ldots .)_\nu :$$

apply the formula (A), this becomes

$$\frac{d^2 \log_\epsilon al(u_1 u_2 \ldots .)_{2\alpha-1}}{du_\alpha du_\nu} = -\frac{d}{du_\nu} \alpha\lambda(u_1 \ldots .)_\alpha + \frac{d}{du_\alpha} \alpha\lambda(u_1 - \overset{2\nu-1}{\mathrm{K}_1} \ldots .)_\nu .$$

But

$$\frac{d}{du_\nu} \alpha\lambda(u_1 \ldots .)_\alpha = -\frac{e^2{}_{2\alpha-1} e^2{}_{2\nu-1}}{a_{2\alpha-1} - a_{2\nu-1}} \cdot \frac{al^2(u_1 \ldots .)_{2\nu-1}}{al^2(u_1 \ldots .)_{2\alpha-1}} .$$

Also, using formulæ (1) and (2) of section 1,

$$\frac{d}{du_\alpha} \alpha\lambda(u_1 - \overset{2\nu-1}{\mathrm{K}_1} \ldots .)_\nu = \pm e^2{}_{2\alpha-1} e^2{}_{2\nu-1} al^2(u_1 \ldots .)_{2\nu-1} al^2(u_1 \ldots .)_{2\alpha-1}$$
$$. \Sigma^2 \left\{ \frac{\sqrt{\mathrm{R}x_\mu}}{(x_\mu - a_{2\alpha-1})(x_\mu - a_{2\nu-1}) \mathrm{L}'(x_\mu)} \right\} .$$

But by a formula (Crelle 47, page 292) proved by Weierstrass in his second paper, page 322, we have

$$\frac{d \, . \, al(u_1 u_2 \ldots .)_{2\alpha-1}}{du_\nu} = -\frac{e^2{}_{2\nu-1}}{\sqrt{\pm (a_{2\alpha-1} - a_{2\nu-1})}} al(u_1 \ldots .)_{2\nu-1} al(u_1 \ldots .)_{2\alpha-1,\, 2\nu-1},$$

whence

$$\frac{d \, . \log_\epsilon al(u_1 u_2 \ldots .)_{2\alpha-1}}{du_\nu} = -e^2{}_{2\nu-1} al^2(u_1 \ldots .)_{2\nu-1} \Sigma \left\{ \frac{\mathrm{R}(x_\mu)}{(x_\mu - a_{2\alpha-1})(x_\mu - a_{2\nu-1}) \mathrm{L}'x_\mu} \right\},$$

and

$$\frac{d \, . \log_\epsilon al(u_1 u_2 \ldots .)_{2\nu-1}}{du_\alpha} = -e^2{}_{2\alpha-1} al^2(u_1 \ldots .)_{2\alpha-1} \Sigma \left\{ \frac{\mathrm{R}x_\mu}{(x_\mu - a_{2\alpha-1})(x_\mu - a_{2\nu-1}) \mathrm{L}'x_\mu} \right\};$$

whence we see that

$$\frac{du}{du_\alpha} \alpha\lambda(u_1 - \overset{2\nu-1}{\mathrm{K}_1} \ldots .)_\nu = \frac{d \log_\epsilon \alpha\lambda(u_1 u_2 \ldots .)_{2\alpha-1}}{du_\nu} \cdot \frac{d \log_\epsilon \alpha\lambda(u_1 u_2 \ldots .)_{2\nu-1}}{du_\alpha},$$

and we have

$$\frac{d^2 \log_\epsilon al(u_1 \ldots .)_{2\alpha-1}}{du_\alpha du_\nu} = \frac{d \log_\epsilon \alpha\lambda(u_1 u_2 \ldots .)_{2\alpha-1}}{du_\nu} \cdot \frac{d \log_\epsilon \alpha\lambda(u_1 u_2 \ldots .)_{2\nu-1}}{du_\alpha}$$
$$+ \frac{e^2{}_{2\alpha-1} \; e^2{}_{2\nu-1}}{a_{2\nu-1} - a_{2\alpha-1}} \cdot \frac{al^2(u_1 \ldots .)_{2\nu-1}}{al^2(u_1 \ldots .)_{2\alpha-1}} .$$

This proposition has been proved by Brioschi, 'Annali di Matematica,' tom. i., in a paper entitled "Sopra alcune proprietà delle funzioni Abeliani," Section 4. Brioschi, however, uses the notation in Weierstrass's second paper.

Hence we may manifestly assume, if J be some constant,

$$\frac{d\log_\epsilon al(u_1u_2\ldots)_{2a-1}}{du_\nu} = J - \alpha\lambda(u_1+\overset{2a-1}{K}_1-\overset{2\nu-1}{K}_1)_\nu + \alpha\lambda(u_1-\overset{2\nu-1}{K}_1\ldots)_\nu :$$

put in this $u_1-\overset{2a-1}{K}_1$ for u, and we have

$$-\frac{d\log_\epsilon al(u_1u_2\ldots)_{2a-1}}{du_\nu} = J-\alpha\lambda(u_1-\overset{2\nu-1}{K}_1)_\nu+\alpha\lambda(u_1-\overset{2a-1}{K}_1-\overset{2\nu-1}{K}_1\ldots)_\nu.$$

Hence, by addition,

$$0=2J-\alpha\lambda(u_1+\overset{2a-1}{K}_1-\overset{2\nu-1}{K}_1)_\nu+\alpha\lambda(u_1-\overset{2a-1}{K}_1-\overset{2\nu-1}{K}_1\ldots)_\nu ;$$

and this must be true for all values of u: put for u_1, $\overset{2\nu-1}{K}_1$, and

$$2J=\alpha\lambda(\overset{2a-1}{K}_1\ldots)_\nu-\alpha\lambda(-\overset{2a-1}{K}_1\ldots)_\nu,$$

or

$$J=\alpha\lambda(\overset{2a-1}{K}_1\ldots)_\nu=\overset{2a-1}{J}_\nu,$$

which determine the arbitrary constant, and we have

$$\frac{d\log_\epsilon al(u_1u_2\ldots u_n)_{2a-1}}{du_\nu}=\overset{2a-1}{J}_\nu-\alpha\lambda(u_1+\overset{2a-1}{K}_1-\overset{2\nu-1}{K}_1)_\nu+\alpha\lambda(u_1-\overset{2\nu-1}{K}_1\ldots)_\nu.$$

Section 5.—It may be proved by the help of equation A of last section that the expression

$$\Sigma_\nu\{-\overset{2\nu-1}{J}_\nu-\alpha\lambda(u_1-\overset{2\nu-1}{K}_1\ldots)_\nu\}du_\nu$$

is a perfect differential.

Now let us define two new transcendents as follows:—

$$d\log_\epsilon \mathrm{Al}(u_1, u_1\ldots)=-\Sigma_\nu\{\overset{2\nu-1}{J}_\nu+\alpha\lambda(u_1-\overset{2\nu-1}{K}_1\ldots)\}du_\nu,$$

and

$$al(u_1u_2\ldots)_a=\frac{\mathrm{Al}(u_1u_2\ldots)_a}{\mathrm{Al}(u_1u_2\ldots)}.$$

Combining these equations together, and making use of equation (1) of last section,

$$d\log_\epsilon \mathrm{Al}(u_1u_2\ldots)_a=-\Sigma_\nu\{\overset{2\nu-1}{J}_\nu-\overset{a}{J}_\nu+\alpha\lambda(u_1-\overset{2\nu-1}{K}_1+\overset{a}{K}_1\ldots)_\nu\}du_\nu.$$

Now putting $u_1+\overset{a}{K}_1$, $u_2+\overset{a}{K}_2,\ldots$ for $u_1u_2\ldots$, we have

$$d\log_\epsilon \mathrm{Al}(u_1+\overset{a}{K}_1,\ u_2+\overset{a}{K}_2,\ldots)$$

$$=-\Sigma_\nu\{\overset{2\nu-1}{J}_\nu+\alpha\lambda(u_1+\overset{a}{K}_1-\overset{2\nu}{K}_1\ldots)_\nu\}du_\nu,$$

or

$$d\log_\epsilon \mathrm{Al}(u_1+\overset{a}{K}_1\ldots)-d\log_\epsilon \mathrm{Al}(u_1\ldots)$$

$$= -\Sigma_\nu\left\{\overset{\alpha}{J}_\nu \cdot - \frac{d\log_\epsilon al(u\ldots\ldots)_\alpha}{du_\nu}\right\}du_\nu;$$

also

$$d\log_\epsilon \text{Al}(u_1+2\overset{\alpha}{K}_1,\ldots\ldots) - d\log_\epsilon \text{Al}(u+\overset{\alpha}{K}_1\ldots\ldots)$$

$$= -\Sigma_\nu\left\{\overset{\alpha}{J}_\nu + \frac{d\log_\epsilon al(u_1\ldots\ldots)_\alpha}{du_\nu}\right\}du_\nu,$$

or

$$d\log_\epsilon \text{Al}(u_1+2\overset{\alpha}{K}_1\ldots\ldots) - d\log_\epsilon \text{Al}(u_1u_2\ldots\ldots) = -\Sigma_\nu 2\overset{\alpha}{J}_\nu du_\nu;$$

whence we see that

$$\text{Al}\,(u_1+2\overset{\alpha}{K}_1\ldots\ldots) = (-1)^\alpha \epsilon^{-2\Sigma_\nu \overset{\alpha}{J}_\nu(u_\nu+\overset{\alpha}{K}_\nu)}\text{Al}(u_1\ldots\ldots). \quad . \quad . \quad . \quad (1)$$

Put $u_1+2\overset{\beta}{K}_1$ for u_1, and remember that

$$(\overset{\alpha}{J}_\nu+\overset{\beta}{J}_\nu)(\overset{\alpha}{K}_\nu+\overset{\beta}{K}_\nu)+\overset{\beta}{K}_\nu\overset{\alpha}{J}_\nu-\overset{\alpha}{K}_\nu\overset{\beta}{J}_\nu=\overset{\alpha}{J}_\nu\overset{\alpha}{K}_\nu+\overset{\beta}{J}_\nu\overset{\beta}{K}_\nu+2\overset{\beta}{K}_\nu\overset{\alpha}{J}_\nu,$$

and we have

$$\text{Al}(u_1+2\overset{\alpha}{K}_1+2\overset{\beta}{K}_1\ldots\ldots)$$

$$=(-1)^{\alpha+\beta}\epsilon^{-2\Sigma\{(\overset{\alpha}{J}_\nu+\overset{\beta}{J}_\nu)(u_\nu+\overset{\alpha}{K}_\nu+\overset{\beta}{K}_\nu)+(\overset{\beta}{K}_\nu\overset{\alpha}{J}_\nu-\overset{\alpha}{K}_\nu\overset{\beta}{J}_\nu)\}}\text{Al}(u_1\ldots\ldots). \quad . \quad (2)$$

Interchanging α and β with one another, we have

$$\epsilon^{2\Sigma_\nu(\overset{\alpha}{K}_\nu\overset{\beta}{J}_\nu-\overset{\alpha}{J}_\nu\overset{\beta}{K}_\nu)}=\epsilon^{-2\Sigma_\nu(\overset{\alpha}{K}_\nu\overset{\beta}{J}_\nu-\overset{\alpha}{J}_\nu\overset{\beta}{K}_\nu)};$$

whence

$$\Sigma(\overset{\alpha}{K}_\nu\overset{\beta}{J}_\nu-\overset{\alpha}{J}_\nu\overset{\beta}{K}_\nu)=\mu\cdot\frac{\pi}{2}\cdot i,$$

where μ is an integer.

Section 6.—It may indeed be proved by direct integration that

$$\Sigma(\overset{\alpha}{K}_\nu\overset{\beta}{J}_\nu-\overset{\alpha}{J}_\nu\overset{\beta}{K}_\nu)=\pm\frac{\pi i}{2}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where the upper or lower sign is to be taken according as α is greater or less than β. See on this subject a memoir by Brioschi in the 'Annali di Matematica,' vol. i. p. 12, in which the method of treating theorems of this nature by direct integration is fully discussed.

The following formulæ are also true :—

$$\left.\begin{aligned}
&\Sigma_\nu(K_{\nu,c}J_{\nu,c'}-J_{\nu,c}K_{\nu,c'})=0,\\
&\Sigma_\nu(K'_{\nu,c}J'_{\nu,c'}-J'_{\nu,c}K'_{\nu,c'})=0,\\
&\Sigma_\nu(K_{\nu,c}J'_{\nu,c'}-J_{\nu,c}K'_{\nu,c'})=0,\\
&\Sigma_\nu(K_{\nu,c}J'_{\nu,c}-J_{\nu,c}K'_{\nu,c})=\frac{\pi}{2}.
\end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

It will be sufficient if we prove the first and last of these formulæ. The first is proved by taking the values of $K_{\nu,c}$, $J_{\nu,c}$ already given in sections 1 and 4.

$$\Sigma(K_{\nu,c}J_{\nu,c'}-K_{\nu,c'}J_{\nu,c})=\Sigma\{(\overset{2c-1}{K}_\nu-\overset{2c}{K}_\nu)(\overset{2c'-1}{J}_\nu-\overset{2c'}{J}_\nu)-(\overset{2c'-1}{K}_\nu-\overset{2c'}{K}_\nu)(\overset{2c-1}{J}_\nu-\overset{2c}{J}_\nu)\}$$

$$=\Sigma_\nu(\overset{2c-1}{K}_\nu\overset{2c'-1}{J}_\nu-\overset{2c'-1}{K}_\nu\overset{2c-1}{J}_\nu)+\Sigma_\nu(\overset{2c}{K}_\nu\overset{2c'}{J}_\nu-\overset{2c'}{K}_\nu\overset{2c}{J}_\nu)-\Sigma_\nu(\overset{2c}{K}_\nu\overset{2c'-1}{J}_\nu-\overset{2c'-1}{K}_\nu\overset{2c}{J}_\nu)-\Sigma_\nu(\overset{2c-1}{K}_\nu\overset{2c'}{J}_\nu-\overset{2c'-1}{K}_\nu\overset{2c}{J}_\nu)=0.$$

$$\Sigma_\nu(K_{\nu,c}J'_{\nu,c}-J_{\nu,c}K'_{\nu,c})=-i\Sigma_\nu\{(\overset{2c-1}{K}_\nu-\overset{2c}{K}_\nu)(\overset{0}{J}_\nu-\overset{1}{J}_\nu+\overset{2}{J}_\nu-\overset{3}{J}_\nu+\ldots\ldots+\overset{2c-2}{J}_\nu-\overset{2c-1}{J}_\nu)$$

$$-(\overset{2c-1}{J}_\nu-\overset{2c}{J}_\nu)(\overset{0}{K}_\nu-\overset{1}{K}_\nu+\overset{2}{K}_\nu-\overset{3}{K}_\nu+\ldots\ldots\overset{2c-2}{K}_\nu-\overset{2c-1}{K}_\nu)\}$$

$$=\frac{\pi}{2}.$$

Section 7.—Let now

$$\omega_\nu=m_1K_{\nu,1}+m_2K_{\nu,2}+\ldots\ldots+m_nK_{\nu,n},$$

$$\omega'_\nu=r_1K'_{\nu,1}+r_2K'_{\nu,2}+\ldots\ldots+r_nK'_{\nu,n},$$

$$\epsilon_\nu=m_1J_{\nu,1}+m\ J_{\nu,2}+\ldots\ldots+m_nJ_{\nu,n},$$

$$\epsilon'_\nu=r_1J'_{\nu,1}+r_2J'_{\nu,2}+\ldots\ldots+r_nJ'_{\nu,n};$$

then we shall have

$$\mathrm{Al}(u_1+2\omega_1\ \ldots\ldots)=\epsilon^{-2\Sigma_\nu\epsilon_\nu(u_\nu+\omega_\nu)}\mathrm{Al}(u_1\ldots\ ),\ldots\ldots\quad(1)$$

$$\mathrm{Al}(u\ +2\omega'_1i\ldots\ldots)=\epsilon^{-2\Sigma_\nu\epsilon'_\nu(u_\nu+\omega'_\nu i)i}.(\mathrm{Al}(u_1\ldots\ldots).\ \ldots\ldots\quad(2)$$

We shall prove the first of these formulæ.

We easily deduce from equation (1), section 5, that

$$\mathrm{Al}(u_1+2m\overset{\alpha}{K}_1\ldots\ldots)=\epsilon^{-2\Sigma_\nu m\overset{\alpha}{J}_\nu(u_\nu+m\overset{\alpha}{K}_\nu)}\mathrm{Al}.(u_1\ldots\ldots),$$

where m is an integer. Hence

$$\mathrm{Al}(u_1+2m\overset{\alpha}{K}_1+2r\overset{\beta}{K}_1\ldots\ldots)=$$

$$\epsilon^{-2\Sigma_\nu m\overset{\alpha}{J}_\nu(u_\nu+2r\overset{\beta}{K}_\nu+\overset{\alpha}{K}_\nu)}\epsilon^{-2\Sigma_\nu r\overset{\beta}{J}_\nu(u_\nu+r\overset{\beta}{K}_\nu)}\mathrm{Al}(u\ldots\ldots)$$

$$=\epsilon^{-2\Sigma_\nu\{(m\overset{\alpha}{J}_\nu+r\overset{\beta}{J}_\nu)(u_\nu+r\overset{\beta}{K}_\nu+m\overset{\alpha}{K}_\nu)+mr(\overset{\beta}{K}_\nu\overset{\alpha}{J}_\nu-\overset{\alpha}{K}_\nu\overset{\beta}{J}_\nu)\}}\mathrm{Al}(u\ldots\ldots)$$

$$=\epsilon^{-2\Sigma_\nu(m\overset{\alpha}{J}_\nu+r\overset{\beta}{J})(u_\nu+r\overset{\beta}{K}_\nu+m\overset{\alpha}{K}_\nu)}\mathrm{Al}(u_1u\ \ldots\ldots).$$

In precisely the same manner we shall find, continuing the process,

$$\mathrm{Al}(u_1+2m\overset{\alpha}{\mathrm{K}}_1+2r\overset{\beta}{\mathrm{K}}_1+2s\overset{\gamma}{\mathrm{K}}_1\ldots\ldots)$$

$$=e^{-2\Sigma_\nu\{(m\overset{\alpha}{\mathrm{J}}_\nu+r\overset{\beta}{\mathrm{J}}_\nu+s\overset{\gamma}{\mathrm{J}}_\nu)(u_\nu+m\overset{\alpha}{\mathrm{K}}_\nu+r\overset{\beta}{\mathrm{K}}_\nu+s\overset{\gamma}{\mathrm{K}}_\nu)}$$

$$e^{-2\Sigma_\nu\{ms(\overset{\alpha}{\mathrm{J}}_\nu\overset{\gamma}{\mathrm{K}}_\nu-\overset{\gamma}{\mathrm{J}}_\nu\overset{\alpha}{\mathrm{K}}_\nu)+ns(\overset{\beta}{\mathrm{J}}_\nu\overset{\gamma}{\mathrm{K}}_\nu-\overset{\beta}{\mathrm{K}}_\nu\overset{\gamma}{\mathrm{J}}_\nu)\}}\,\mathrm{Al}(u_1\ldots\ldots)$$

$$=e^{2\Sigma_\nu\{(m\overset{\alpha}{\mathrm{J}}_\nu+\nu\overset{\beta}{\mathrm{J}}_\nu+s\overset{\gamma}{\mathrm{J}}_\nu)(u_\nu+m\overset{\alpha}{\mathrm{K}}_\nu+\nu\overset{\beta}{\mathrm{K}}_\nu+s\overset{\gamma}{\mathrm{K}}_\nu)\}}\,\mathrm{Al}(u_1\ldots\ldots),$$

from which we may infer the truth of the theorem.

Section 8.—Now assume

$$u_1=\frac{1}{\pi}(\mathrm{K}_{1,1}v_1+\mathrm{K}_{1,2}v_2+\ldots\ldots+\mathrm{K}_{1,n}v_n),$$

$$u_2=\frac{1}{\pi}(\mathrm{K}_{2,1}v_1+\mathrm{K}_{2,2}v_2+\ldots\ldots+\mathrm{K}_{2,n}v_n),$$

$$\ldots=\qquad\ldots\ldots$$

$$u_n=\frac{1}{\pi}(\mathrm{K}_{n,1}v_1+\mathrm{K}_{n,2}v_2+\ldots\ldots+\mathrm{K}_{n,n}v_n);$$

whence we obtain equations of the form

$$v_1=\pi(\mathrm{G}_{1,1}u_1+\mathrm{G}_{2,1}u_2+\ldots\ldots+\mathrm{G}_{n,1}u_n),$$

$$v_2=\pi(\mathrm{G}_{1,2}u_1+\mathrm{G}_{2,2}u_2+\ldots\ldots+\mathrm{G}_{n,2}u_n),$$

$$\ldots=\qquad\ldots\ldots$$

$$v_n=\pi(\mathrm{G}_{1,n}u_1+\mathrm{G}_{2,n}u_2+\ldots\ldots+\mathrm{G}_{n,n}u_n);$$

from these equations we have manifestly

$$\left.\begin{array}{ll}\Sigma_c\mathrm{K}_{\nu,c}\mathrm{G}_{\nu,c}=1, & \Sigma_\nu\mathrm{K}_{\nu,c}\mathrm{G}_{\nu,c}=1,\\ \Sigma_c\mathrm{K}_{\nu,c}\mathrm{G}_{\nu',c}=0, & \Sigma_\nu\mathrm{K}_{\nu,c}\mathrm{G}_{\nu,c'}=0.\end{array}\right\}\quad\ldots\ldots\ldots\quad(\mathrm{B})$$

Then from the first of equations (2), section 6, we have

$$\Sigma_\nu(\mathrm{G}_{\nu',c'}\mathrm{K}_{\nu,c}\mathrm{J}_{\nu,c'}-\mathrm{G}_{\nu',c'}\mathrm{J}_{\nu,c}\mathrm{K}_{\nu,c'})=0,$$

or
$$\Sigma_\nu\{\mathrm{K}_{\nu,c}\Sigma_{c'}\mathrm{G}_{\nu',c'}\mathrm{J}_{\nu,c'}-\mathrm{J}_{\nu,c}\Sigma_{c'}\mathrm{G}_{\nu',c'}\mathrm{K}_{\nu,c'}\}=0,$$

or
$$\Sigma_\nu\{\mathrm{K}_{\nu,c}\Sigma_{c'}(\mathrm{G}_{\nu',c'}\mathrm{J}_{\nu,c'}-\mathrm{J}_{\nu',c'}\mathrm{G}_{\nu,c'})\}$$

$$+\Sigma_\nu\{\mathrm{K}_{\nu,c}\Sigma_{c'}\mathrm{G}_{\nu,c'}\mathrm{J}_{\nu',c'}-\mathrm{J}_{\nu,c}\Sigma_{c'}\mathrm{G}_{\nu',c'}\mathrm{K}_{\nu,c'}\}=0.$$

But
$$\Sigma_\nu\{\mathrm{K}_{\nu,c}\Sigma_{c'}\mathrm{G}_{\nu,c'}\mathrm{J}_{\nu',c'}-\mathrm{J}_{\nu,c}\Sigma_{c'}\mathrm{G}_{\nu',c'}\mathrm{K}_{\nu,c'}\}$$

$$=\Sigma_{c'}\{\mathrm{J}_{\nu',c'}\Sigma_\nu\mathrm{K}_{\nu,c}\mathrm{G}_{\nu,c'}\}-\Sigma_\nu\{\mathrm{J}_{\nu,c}\Sigma_{c'}\mathrm{G}_{\nu',c'}\mathrm{K}_{\nu,c'}\}$$

$$=\mathrm{J}_{\nu',c}-\mathrm{J}_{\nu',c}=0;$$

consequently we shall have

$$\Sigma_\nu\{K_{\nu,c}\Sigma_{c'}(G_{\nu',c'}J_{\nu,c'}-J_{\nu',c'}G_{\nu,c'})\}=0.$$

This equation must hold good for all values of c; wherefore, putting

$$p_\nu=\Sigma_{c'}(G_{\nu',c'}J_{\nu,c'}-J_{\nu',c'}G_{\nu,c'}),$$

we shall have

$$K_{1,1}p_1+K_{2,1}p_2+K_{3,1}p_3+\ldots\ldots+K_{n,1}p_n=0,$$

$$K_{1,2}p_1+K_{2,2}p_2+K_{3,2}p_3+\ \ldots+K_{n,2}p_n=0,$$

$$K_{1,n}p_1+K_{2,n}p_2+K_{3,n}p_3+\ldots\ldots+K_{n,n}p_n=0.$$

These equations give $p_1=p_2=\ldots\ldots=p_n=0$,

or $$\Sigma_{c'}(G_{\nu',c'}J_{\nu,c'}-J_{\nu',c'}G_{\nu,c'}\}=0,$$

or $$\Sigma_cG_{\nu',c}J_{\nu,c}=\Sigma_cG_{\nu,c}J_{\nu',c}. \qquad (1)$$

Now if we put

$$\epsilon_{\nu,c}=\Sigma_{c'}G_{\nu,c'}J_{c,c'},$$

$$\delta_{\nu,c}=\Sigma_{c'}G_{c',\nu}K'_{c',c}\pi,$$

$$\sigma_{\nu,c}=G_{\nu,c}\pi,$$

then we shall have

$$J_{\nu,c}=\Sigma_{c'}\epsilon_{\nu,c'}K_{c',c}, \qquad (2)$$

$$J'_{\nu,c}=\tfrac{1}{2}\sigma_{\nu,c}+\Sigma_{c'}\epsilon_{\nu,c'}K_{c',c}. \qquad (3)$$

The first of these formulæ may be proved thus:

since $$\Sigma_cG_{\nu,c}J_{\nu',c}=\Sigma_cG_{\nu',c}J_{\nu,c},$$

therefore $$\Sigma_c\Sigma_\nu G_{\nu,c}K_{\nu,c'}J_{\nu',c}=\Sigma_c\Sigma_\nu G_{\nu',c}J_{\nu,c}K_{\nu,c'};$$

that is (see equations B), $$J_{\nu',c'}=\Sigma_\nu\Sigma_cG_{\nu',c}J_{\nu,c}\,.\,K_{\nu,c'},$$

or $$J_{\nu',c}=\Sigma_\nu\epsilon_{\nu',\nu}K_{\nu,c}, \text{ whence}$$

$$J_{\nu,c}=\Sigma_{c'}\epsilon_{\nu,c'}K_{c',c}.$$

Also, for the second of these formulæ, since by equations (2), section 6, we have

$$\Sigma_\nu(K_{\nu,c}J'_{\nu,c'}-J_{\nu,c}K'_{\nu,c'})=0, \text{ when } c \text{ and } c' \text{ are unequal,}$$

$$=\frac{\pi}{2}, \text{ when } c \text{ and } c' \text{ are equal;}$$

hence $$\Sigma_\nu\{\Sigma_c(G_{\nu',c}K_{\nu,c})J'_{\nu,c'}-\Sigma_c(J_{\nu,c}G_{\nu',c})K'_{\nu,c'}\}$$

$$=\frac{\pi}{2}G_{\nu',c'}.$$

Hence
$$J'_{\nu',c'}=\frac{\pi}{2}\cdot G_{\nu',c'}+\Sigma_\nu\Sigma_c(G_{\nu',c}J_{\nu,c})K'_{\nu,c'}$$
$$=\frac{\pi}{2}G_{\nu',c'}+\Sigma_\nu\epsilon_{\nu',\nu}K'_{\nu,c'},$$
or
$$J'_{\nu,c}=\frac{\pi}{2}G_{\nu,c}+\Sigma_{c'}\epsilon_{\nu,c'}K'_{c',c}.$$

This formula may be written thus, by merely changing the letters:

$$J'_{\nu,c}=\frac{\pi}{2}G_{\nu,c}+\Sigma_\alpha\Sigma_\beta(G_{\nu,\beta}J_{\alpha,\beta}K'_{\alpha,c}),$$
$$J'_{\nu,c}K'_{\nu,c'}=\frac{\pi}{2}G_{\nu,c}K'_{\nu,c'}+\Sigma_\alpha\Sigma_\beta(G_{\nu,\beta}J_{\alpha,\beta}K'_{\alpha,c}K'_{\nu,c'}),$$
and
$$J'_{\nu,c'}K'_{\nu,c}=\frac{\pi}{2}G_{\nu,c'}K'_{\nu,c}+\Sigma_\alpha\Sigma_\beta(G_{\nu,\beta}J_{\alpha,\beta}K'_{\alpha,c'}K'_{\nu,c})$$
$$=\frac{\pi}{2}G_{\nu,c'}K'_{\nu,c}+\Sigma_\alpha\Sigma_\beta(G_{\alpha,\beta}J_{\nu,\beta}K'_{\alpha,c'}K'_{\nu,c});$$

therefore
$$\Sigma_\nu(J'_{\nu,c}K'_{\nu,c'}-J'_{\nu,c'}K'_{\nu,c})=\frac{\pi}{2}\Sigma_\nu(G_{\nu,c}K'_{\nu,c'}-G_{\nu,c'}K'_{\nu,c})$$
$$-\Sigma_\beta\{\Sigma_\nu(G_{\nu,\beta}K'_{\nu,c'})\Sigma_\alpha(J_{\alpha,\beta}K'_{\alpha,c})-\Sigma_\alpha(G_{\alpha,\beta}K'_{\alpha,c'})\Sigma_\nu(J_{\nu,\beta}K'_{\nu,c})\}$$
$$=\frac{\pi}{2}\Sigma_\nu(G_{\nu,c}K'_{\nu,c'}-G_{\nu,c'}K'_{\nu,c}).\quad\text{But }\Sigma_\nu(J'_{\nu,c}K'_{\nu,c'}-J'_{\nu,c'}K'_{\nu,c})=0;$$
hence
$$\Sigma_\nu G_{\nu,c}K'_{\nu,c'}=\Sigma_\nu G_{\nu,c'}K'_{\nu,c}.\quad\ldots\ldots\ldots \tag{4}$$

Section 9.—Let us now put

$$E(u_1u_2u_3\ldots\ldots)=\tfrac{1}{2}\sum_{\nu,c}u_\nu u_c\epsilon_{\nu,c},\ \text{then}$$
$$E(u_1u_2u_3\ldots\ldots)=\tfrac{1}{2}\Sigma_\nu\Sigma_c\Sigma_\mu G_{\nu,\mu}J_{c,\mu}u_\nu u_c,$$
$$E(u_1+2\omega_1,\ u_2+2\omega_2\ldots\ldots)=\tfrac{1}{2}\Sigma_\nu\Sigma_c\Sigma_\mu G_{\nu,\mu}J_{c,\mu}(u_\nu+2\omega_\nu)(u_c+2\omega_c)$$
$$=E_1(u_1,\ u_2\ldots\ldots u_3)+\Sigma_\nu\Sigma_c\Sigma_\mu\omega_\nu u_c G_{\nu,\mu}J_{c,\mu}+\Sigma_\nu\Sigma_c\Sigma_\mu\omega_c u_\nu G_{\nu,\mu}J_{c,\mu}$$
$$+2\Sigma_\nu\Sigma_c\Sigma_\mu\omega_\nu\omega_c G_{\nu,\mu}J_{c,\mu}.$$

Now
$$\Sigma_\nu G_{\nu,\mu}\omega_\nu=\Sigma_\nu G_{\nu,\mu}(m_1K_{\nu,1}+m_2K_{2,2}+\ldots\ldots)=m_\mu:$$
hence
$$\Sigma_\nu\Sigma_c\Sigma_\mu\omega_\nu u_c G_{\nu,\mu}J_{c,\mu}=\Sigma_\nu\Sigma_c\Sigma_\mu\omega_c u_\nu G_{\nu,\mu}J_{c,\mu}=\Sigma_\nu\epsilon_\nu u_\nu;$$
also
$$2\Sigma_\nu\Sigma_c\Sigma_\mu G_{\nu,\mu}J_{c,\mu}\omega_\nu\omega_c=2\Sigma\epsilon_\nu\omega_\nu$$
$$E(u_1+2\omega_1\ldots\ldots)=E(u_1\ldots\ldots)+2\Sigma_\nu\epsilon_\nu(u_\nu+\omega_\nu).$$

Now let us define a symbol,

$$J_c(v_1, v_2 \ldots) = g \,.\, \epsilon^{E(u_1 u_2 \ldots\ldots)} Al(u_1 u_2 \ldots);$$

then, when v_1 becomes $v_1 + 2m_1\pi \ldots$, u_1 becomes

$$u_1 + 2(K_{1,1}m_1 + K_{1,2}m_2 + K_{1,3}m_3 + \ldots) = u_1 + 2\omega_1,$$

and therefore $\qquad J_c(v_1 + 2m_1\pi,\ v_2 + 2m_2\pi,\ + \ldots) =$

$$g\epsilon^{E(u_1 u_2 \ldots\ldots u_n) + 2\Sigma_n \epsilon_\nu (u_1 + \omega_\nu)} \epsilon^{-2\Sigma_n \epsilon_\nu (u_\nu + \omega_\nu)} Al(u_1 u_2 \ldots)$$

$$= g\epsilon^{E(u_1 u_2 \ldots\ldots u_n)} Al(u_1 u_2 \ldots u_n) = J_c(v_1 v_2 \ldots).$$

Section 10.—Let us now recall the values of $\delta_{\nu, c}$ (section 8) defined by the equation $\delta_{\nu, c} = \Sigma_{c'} G_{c', \nu} K'_{c', c} \,.\, \pi$, and let us assume

$$\delta_\nu = r_1 \delta_{\nu, 1} + r_2 \delta_{\nu, 2} + r_3 \delta_{\nu, 3} + \ldots r_n \delta_{\nu, n},$$

and let us ascertain the values of $u_1 u_2 u_3 \ldots$ when $v_1 v_2 \ldots$ become $v_1 + \delta_1 i$, $v_2 + \delta_2 i, \ldots$ Thus u_1 becomes

$$\frac{1}{\pi}(K_{1,1}v_1 + K_{1,2}v_2 + \ldots K_{1,n}v_n) + \frac{1}{\pi}(K_{1,1}\delta_1 + K_{1,2}\delta_2 + \ldots K'_{1,n}\delta_n)i =$$

$$u_1 + K_{1,1}(r_1 \Sigma_\nu G_{\nu,1} K'_{\nu,1} + r_2 \Sigma_\nu G_{\nu,1} K'_{\nu,2} + r_3 \Sigma_\nu G_{\nu,1} K'_{\nu,3} + \ldots)i$$

$$+ K_{1,2}(r_1 \Sigma_\nu G_{\nu,2} K'_{\nu,1} + r_2 \Sigma_\nu G_{\nu,2} K'_{\nu,2} + r_3 \Sigma_\nu G_{\nu,2} K'_{\nu,3} + \ldots)i$$

$$+ K_{1,3}(r_1 \Sigma_\nu G_{\nu,3} K'_{\nu,1} + r_2 \Sigma_\nu G_{\nu,3} K'_{\nu,2} + r_3 \Sigma_\nu G_{\nu,3} K'_{\nu,3} + \ldots)i$$

$$+ \ldots$$

$$= u_1 + (r_1 \Sigma_\mu \Sigma_\nu G_{\nu,\mu} K'_{\nu,1} K_{1,\mu} + r_2 \Sigma_\mu \Sigma_\nu G_{\nu,\mu} K'_{\nu,2} K_{1,\mu} + \ldots)$$

$$= u_1 + r_1 K'_{1,1} + r_2 K'_{1,2} + r_3 K'_{1,3} + \ldots = u_1 + \omega'_1 i,$$

so u_2 becomes $u_2 + \omega'_2 i$, u_3, $u_3 + \omega'_3 i, + \ldots$

We will now investigate the value of

$$J_c(v_1 + 2\delta_1 i,\ v_2 + 2\delta_2 i, \ldots)$$

$$= g\epsilon^{E(u_1 + 2\omega'_1 i,\ u_2 + 2\omega'_2 i, \ldots\ldots)} Al(u_1 + 2\omega'_1 i,\ u_2 + 2\omega'_2 i, \ldots).$$

Now $E(u_1 + 2\omega' i,\ u_2 + 2\omega'_2 i \ldots) = E(u_1,\ u_2 u_3 \ldots)$

$$+ i\Sigma_\nu \Sigma_c \Sigma_\mu \omega'_\nu u_c G_{\nu,\mu} J_{c,\mu} + i\Sigma_\nu \Sigma_c \Sigma_\mu G_{\nu,\mu} J_{c,\mu} \omega'_c u_\nu - 2\Sigma_\nu \Sigma_c \Sigma_\mu G_{\nu,\mu} J_{c,\mu} \omega'_\nu \omega'_c.$$

But

$$i\Sigma_\nu \Sigma_c \Sigma_\mu \omega'_\nu u_c G_{\nu,\mu} J_{c,\mu} = i\Sigma_\nu \Sigma_c \Sigma_\mu (r_1 K'_{\nu,1} + r_2 K'_{\nu,2} + r_3 K'_{\nu,3} + \ldots) u_c G_{\nu,\mu} J_{c,\mu}.$$

But $$\Sigma_\nu\Sigma_c\Sigma_\mu G_{\nu,\mu}J_{c,\mu}K'_{\nu,\lambda}u_c=\Sigma_c\{\Sigma_\nu\Sigma_\mu G_{\nu,\mu}J_{c,\mu}K'_{\nu,\lambda}\}u_c$$

$$=(\text{by 1 and 3 of section 8})\ \Sigma_c\{J'_{c,\lambda}-\frac{\pi}{2}G_{c,\lambda}\}u_c,$$

and therefore $i\Sigma_\nu\Sigma_c\Sigma_\mu\Sigma_\lambda r_\lambda G_{\nu,\mu}J_{c,\mu}K'_{\nu,\lambda}u_c=i\Sigma_c\{r_1J'_{c,1}+r_2J'_{c,2}+r_3J'_{c,3}+\ldots$

$$-\frac{\pi}{2}(r_1G_{c,1}+r_2G_{c,2}+r_3G_{c,3}+\ldots)\}u_c$$

$$=i\Sigma_c\epsilon'_cu_c-\frac{i}{2}(r_1v_1+r_2v_2+r_3v_3+\ldots)=i\Sigma_c\epsilon'_cu_c-\frac{i}{2}\Sigma_\nu r_\nu v_\nu.$$

Similarly,

$$i\Sigma_\nu\Sigma_c\Sigma_\mu G_{\nu,\mu}J_{c,\mu}\omega'_cu_\nu=i\Sigma_c\epsilon'_cu_c-\frac{i}{2}\Sigma_\nu r_\nu v_\nu.$$

Lastly,

$$\Sigma_\nu\Sigma_c\Sigma_\mu G_{\nu,\mu}J_{c,\mu}\omega'_\nu\omega'_c=$$

$$\Sigma_\nu\Sigma_c\Sigma_\mu G_{\nu,\mu}J_{c,\mu}(r_1K'_{\nu,1}+r_2K'_{\nu,2}+r_3K'_{\nu,3}+\ldots)(r_1K'_{c,1}+\ldots)$$

$$=\sum_{\lambda}\sum_{\lambda'}r_\lambda r_{\lambda'}\sum_{\nu,c,\mu}G_{\nu,\mu}J_{c,\mu}K'_{\nu,\lambda}K'_{c,\lambda'}$$

$$=\sum_{\lambda}\sum_{\lambda'}r_\lambda r_{\lambda'}\Sigma_c\{J'_{c,\lambda}K'_{c,\lambda'}-\frac{\pi}{2}G_{c,\lambda}K'_{c,\lambda'}\}$$

$$=\sum_c\{\Sigma_\lambda r_\lambda J'_{c,\lambda}\Sigma_{\lambda'}r_{\lambda'}K'_{c,\lambda'}\}-\frac{\pi}{2}\Sigma_\lambda\Sigma_{\lambda'}r_{\lambda'}r_\lambda\Sigma_cG_{c,\lambda}K'_{c,\lambda'}$$

$$=\Sigma_c\epsilon'_c\omega'_c-\tfrac{1}{2}\Sigma_\lambda r_\lambda\delta_\lambda.$$

Whence we have

$$J_c(v_1+2\delta_1i,\ v_2+2\delta_2i,\ldots)=g\,.\,\epsilon^{\,2i\Sigma_c\epsilon'_cu_c-i\Sigma_\nu r_\nu v_\nu}\,.\,\epsilon^{-2\Sigma_c\epsilon'_c\omega_c+\Sigma_\lambda r_\lambda\delta_\lambda},$$

$$\epsilon^{-2\Sigma_\nu\epsilon'_\nu(u_\nu+\omega'_\nu i)i}\epsilon^{E(u_1u_2\ldots\ldots)}Al(u_1u_2\ldots)$$

$$=\epsilon^{-\Sigma_\nu r_\nu(v_\nu+\delta_\nu i)i}J_c(v_1v_2v_3\ldots).$$

From this expression, combined with that given in last section, we may develop $Jc(v_1v_2v_3\ldots)$ in a series of exponentials. The full expression is given by Königsberger, Crelle, lxiv. p. 19.

Section 11.—Hitherto our investigations have had reference chiefly to whole periods. We will now investigate some formulæ involving half periods.

To determine $$Al(u_1-\overset{a}{K}_1\ldots).$$

By a former equation, we have

$$d\log_\epsilon Al(u_1+\overset{a}{K}_1\ldots)-d\log_\epsilon Al(u_1\ldots)=-\Sigma_\nu\left\{\overset{a}{J}_\nu-\frac{d\log_\epsilon al(u_1u_2\ldots)_a}{du_\nu}\right\}du_\nu$$

$$\mathrm{Al}(u_1+\overset{a}{\mathrm{K}}_1\ldots\ldots)=\mathrm{C}\epsilon^{-\Sigma\overset{a}{\mathrm{J}}_\nu(u_\nu+\mathrm{C}_\nu)}\mathrm{Al}(u_1\ldots\ldots)al(u_1\ldots\ldots)_a;$$

whence

$$\mathrm{Al}(u_1+2\overset{a}{\mathrm{K}}_1\ldots\ldots)=\mathrm{C}\epsilon^{-\Sigma\overset{a}{\mathrm{J}}_\nu(u_\nu+\mathrm{C}_\nu+\overset{a}{\mathrm{K}}_\nu)}\mathrm{Al}(u_1+\overset{a}{\mathrm{K}}_1\ldots\ldots)\frac{i^{a-2\bar{a}}}{al(u_1\ldots\ldots)_a}$$

$$=\mathrm{C}\epsilon^{-\Sigma\overset{a}{\mathrm{J}}_\nu(2u_\nu+2\mathrm{C}_\nu+\overset{a}{\mathrm{K}}_\nu)}\mathrm{Al}(u_1\ldots\ldots)i^{a-i\bar{a}}.$$

Now put $u_1=-\overset{a}{\mathrm{K}}_1\ldots\ldots$; then, since (Crelle, xlvii. p. 301),

$$\mathrm{Al}(-\overset{a}{\mathrm{K}}_1,\ -\overset{a}{\mathrm{K}}_2\ldots\ldots)=\mathrm{Al}(\overset{a}{\mathrm{K}}_1,\ \overset{a}{\mathrm{K}}_2\ldots\ldots),\text{ we have }\mathrm{C}i^{a-2a}=1,\quad \mathrm{C}_\nu=\frac{\mathrm{K}^a_\nu}{2},$$

and therefore

$$\mathrm{Al}(u_1+\overset{a}{\mathrm{K}}_1\ldots\ldots)=\epsilon^{-\Sigma\overset{a}{\mathrm{J}}_\nu\left(u_\nu+\frac{\overset{a}{\mathrm{K}}_\nu}{2}\right)}\mathrm{Al}(u_1\ldots\ldots)al(u_1\ldots\ldots)_a;$$

whence

$$\mathrm{Al}(u_1-\overset{a}{\mathrm{K}}_1\ldots\ldots)=\epsilon^{\Sigma\overset{a}{\mathrm{J}}_\nu\left(u_\nu-\frac{\overset{a}{\mathrm{K}}_\nu}{2}\right)}\mathrm{Al}(u_1\ldots\ldots)al(u_1\ldots\ldots)_a.$$

We will next investigate the value u_1 assumes when $v_1\ldots\ldots$ becomes $v_1-m_1\pi+\delta_1 i_1,\ldots\ldots$ (see Crelle, xlvii. p. 305).

It is plain that u_1 becomes

$$u_1-\Sigma_\nu m_\nu \mathrm{K}_{1,\nu}+\frac{i}{\pi}\Sigma_\nu \mathrm{K}_{1,\nu}\delta_\nu,$$

and

$$\Sigma_\nu \mathrm{K}_{1,\nu}\delta_\nu=\Sigma_\nu \mathrm{K}_{1,\nu}\Sigma_\mu r_\mu \delta_{\nu,\mu}=\Sigma_\nu \mathrm{K}_{1,\nu}\Sigma_\mu r_\mu \Sigma_\lambda \mathrm{G}_{\lambda,\nu}\mathrm{K}'_{\lambda,\mu}\cdot\pi$$

$$=\pi\Sigma_\mu r_\mu \mathrm{K}'_{1,\mu};$$

and therefore the required value of u_1 is ($m_1m_2\ldots\ldots r_1r_2\ldots\ldots$ being here 0 or 1)

$$u_1-(m_1\mathrm{K}_{1,1}+m_2\mathrm{K}_{1,2}+\ldots\ldots)+i(r_1\mathrm{K}'_{1,1}+r_2\mathrm{K}'_{1,2}+\ldots\ldots)=u_1-\overset{a}{\mathrm{K}}_1\ \text{(Weierstrass, } l.\ c.\text{)}.$$

Section 12.—Hence

$$\mathrm{J}_c(v_1-m_1\pi+\delta_1 i)=$$

$$g\cdot\epsilon^{\mathrm{E}(u_1-\overset{a}{\mathrm{K}}_1,\ u_2-\overset{a}{\mathrm{K}}_2\ldots\ldots)}\mathrm{Al}(u_1-\overset{a}{\mathrm{K}}_1\ldots\ldots).$$

Now

$$\mathrm{E}(u_1-\overset{a}{\mathrm{K}}_1,\ u_2-\overset{a}{\mathrm{K}}\ \ldots\ldots)$$

$$=\tfrac{1}{2}\Sigma_\nu\Sigma_c\Sigma_\mu \mathrm{G}_{\nu,\mu}\mathrm{J}_{c,\mu}(u_\nu-\overset{a}{\mathrm{K}}_\nu)(u_c-\overset{a}{\mathrm{K}}_c)$$

$$=\mathrm{E}(u_1u_2\ldots u_n)-\tfrac{1}{2}\Sigma_\nu\Sigma_c\Sigma_\mu \mathrm{G}_{\nu,\mu}\mathrm{J}_{c,\mu}\overset{a}{\mathrm{K}}_c u_\nu-\tfrac{1}{2}\Sigma_\nu\Sigma_c\Sigma_\mu \mathrm{G}_{\nu,\mu}\mathrm{J}_{c,\mu}\overset{a}{\mathrm{K}}_\nu u_c$$

$$+\tfrac{1}{2}\Sigma_\nu\Sigma_c\Sigma_\mu \mathrm{G}_{\nu,\mu}\mathrm{J}_{c,\mu}\overset{a}{\mathrm{K}}_\nu\overset{a}{\mathrm{K}}_c.$$

But
$$\Sigma_\nu\Sigma_c\Sigma_\mu \mathrm{G}_{\nu,\mu}\mathrm{J}_{c,\mu}\overset{a}{\mathrm{K}}_\nu u_c=$$

$$\Sigma_\nu\Sigma_\mu\Sigma_c(m_1\mathrm{K}_{\nu,1}+m_2\mathrm{K}_{\nu,2}+\ldots-r_1i\mathrm{K}'_{\nu,1}-\ldots)\mathrm{G}_{\nu,\mu}\mathrm{J}_{c,\mu}u_c$$

$$=\Sigma_c\Sigma_\mu \mathrm{J}_{c,\mu}u_c\Sigma_\nu \mathrm{G}_{\nu,\mu}(m_1\mathrm{K}_{\nu,1}+m_2\mathrm{K}_{\nu,2}+m_3\mathrm{K}_{\nu,3}+\ldots)$$

$$-i\Sigma_c\{\Sigma_\nu\Sigma_\mu \mathrm{G}_{\nu,\mu}\mathrm{J}_{c,\mu}(r_1\mathrm{K}'_{\nu,1}+r_2\mathrm{K}'_{\nu,2}+r_3\mathrm{K}'_{\nu,3}+\ldots)\}u_c$$

$$=\Sigma_c\Sigma_\mu m_\mu \mathrm{J}_{c,\mu}u_c-i\Sigma_c\{r_1(\mathrm{J}'_{c,1}-\frac{\pi}{2}\mathrm{G}_{c,1})+r_2(\mathrm{J}'_{c,2}-\frac{\pi}{2}\mathrm{G}_{c,2})+\ldots\}u_c$$

$$=\Sigma_c(m_1\mathrm{J}_{c,1}+m_2\mathrm{J}_{c,2}+m_3\mathrm{J}_{c,3}+\ldots)u_c-i\Sigma_c(r'_1\mathrm{J}'_{c,1}+r_2\mathrm{J}'_{c,2}+r_3\mathrm{J}'_{c,3}+\ldots)u_c$$

$$+\frac{i\pi}{2}\{r_1(\mathrm{G}_{1,1}u_1+\mathrm{G}_{2,1}u_2+\ldots)+r_2(\mathrm{G}_{1,2}u_1+\mathrm{G}_{2,2}u_2+\ldots)+\ldots\}$$

$$=\Sigma_c\epsilon_c u_c-i\Sigma_c\epsilon'_c u_c+\frac{i}{2}\Sigma_\nu r'_\nu v_\nu.$$

Again,

$$\Sigma_\nu\Sigma_c\Sigma_\mu \mathrm{G}_{\nu,\mu}\mathrm{J}_{c,\mu}\overset{a}{\mathrm{K}}_\nu\overset{a}{\mathrm{K}}_c=$$

$$\Sigma_\nu\Sigma_c\Sigma_\mu \mathrm{G}_{\nu,\mu}\mathrm{J}_{c,\mu}\{\Sigma_\lambda m_\lambda \mathrm{K}_{\nu,\lambda}-i\Sigma_\rho r_\rho \mathrm{K}'_{\nu,\rho}\}\{\Sigma_{\lambda'}m_{\lambda'}\mathrm{K}_{c,\lambda'}-i\Sigma_{\rho'}r_{\rho'}\mathrm{K}'_{c,\rho'}\}$$

$$=\Sigma_\lambda\Sigma_{\lambda'}m_\lambda m_{\lambda'}\Sigma_\nu\Sigma_c\Sigma_\mu \mathrm{G}_{\nu,\mu}\mathrm{J}_{c,\mu}\mathrm{K}_{\nu,\lambda}\mathrm{K}_{c,\lambda'}-i\Sigma_\lambda\Sigma_{\rho'}m_\lambda r_{\rho'}\Sigma_\nu\Sigma_c\Sigma_\mu \mathrm{G}_{\nu,\mu}\mathrm{J}_{c,\mu}\mathrm{K}_{\nu,\lambda}\mathrm{K}'_{c,\rho'}$$

$$-i\Sigma_\rho\Sigma_{\lambda'}m_{\lambda'}r_\rho\Sigma_\nu\Sigma_c\Sigma_\mu \mathrm{G}_{\nu,\mu}\mathrm{J}_{c,\mu}\mathrm{K}'_{\nu,\rho}\mathrm{K}_{c,\lambda'}-\Sigma_\rho\Sigma_{\rho'}r_\rho r_{\rho'}\Sigma_\nu\Sigma_c\Sigma_\mu \mathrm{G}_{\nu,\mu}\mathrm{J}_{c,\mu}\mathrm{K}'_{\nu,\rho}\mathrm{K}'_{c,\rho'}$$

$$=\Sigma_\lambda\Sigma_{\lambda'}m_\lambda m_{\lambda'}\Sigma_c\Sigma_\mu(\Sigma_\nu \mathrm{G}_{\nu,\mu}\mathrm{K}_{\nu,\lambda})\mathrm{J}_{c,\mu}\mathrm{K}_{c,\lambda'}-i\Sigma_\lambda\Sigma_{\rho'}m_\lambda r_{\rho'}\Sigma_\nu(\Sigma_c\Sigma_\mu \mathrm{G}_{\nu,\mu}\mathrm{J}_{c,\mu}\mathrm{K}'_{c,\rho'})\mathrm{K}_{\nu,\lambda}$$

$$-i\Sigma_\rho\Sigma_{\lambda'}m_{\lambda'}r_\rho\Sigma_c(\Sigma_\nu\Sigma_\mu \mathrm{G}_{c,\mu}\mathrm{J}_{\nu,\mu}\mathrm{K}'_{\nu,\rho})\mathrm{K}_{c,\lambda'}-\Sigma_\rho\Sigma_{\rho'}r_\rho r_{\rho'}\Sigma_c(\Sigma_\nu\Sigma_\mu \mathrm{G}_{\nu,\mu}\mathrm{J}_{c,\mu}\mathrm{K}'_{\nu,\rho})\mathrm{K}'_{c,\rho'}$$

$$=\Sigma_\lambda\Sigma_{\lambda'}m_\lambda m_{\lambda'}\Sigma_c \mathrm{J}_{c,\lambda}\mathrm{K}_{c,\lambda'}-i\Sigma_\lambda\Sigma_{\rho'}m_\lambda r_{\rho'}\Sigma_\nu\left(\mathrm{J}_{\nu,\rho'}-\frac{\pi}{2}\mathrm{G}_{\nu,\rho'}\right)\mathrm{K}_{\nu,\lambda}$$

$$-i\Sigma_\rho\Sigma_{\lambda'}m_{\lambda'}r_\rho\Sigma_c\left(\mathrm{J}'_{c,\rho}-\frac{\pi}{2}\mathrm{G}_{c,\rho}\right)\mathrm{K}_{c,\lambda'}-\Sigma_\rho\Sigma_{\rho'}r_\rho r_{\rho'}\Sigma_c\left(\mathrm{J}'_{c,\rho}-\frac{\pi}{2}\mathrm{G}_{c,\rho}\right)\mathrm{K}'_{c,\rho'}$$

$$=\Sigma_c(m_1\mathrm{J}_{c,1}+m_2\mathrm{J}_{c,2}+\ldots)(m_1\mathrm{K}_{c,1}+m_2\mathrm{K}_{c,2}+\ldots)$$

$$-i\Sigma_\nu(m_1\mathrm{K}_{\nu,1}+m_2\mathrm{K}_{\nu,2}+\ldots)(r_1\mathrm{J}'_{\nu,1}+r_2\mathrm{J}'_{\nu,2}+r_3\mathrm{J}'_{\nu,3}+\ldots)$$

$$-i\Sigma_c(m_1\mathrm{K}_{c,1}+m_2\mathrm{K}_{c,2}+\ldots)(r_1\mathrm{J}'_{c,1}+r_2\mathrm{J}'_{c,2}+\ldots)$$

$$-\Sigma_c(r_1\mathrm{J}'_{c,1}+r_2\mathrm{J}'_{c,2}+r_3\mathrm{J}'_{c,3}+\ldots)(r_1\mathrm{K}'_{c,1}+r_2\mathrm{K}'_{c,2}+r_3\mathrm{K}'_{c,3}+\ldots)$$

$$+\frac{i\pi}{2}\sum_\lambda\Sigma_{\rho'}m_\lambda r_{\rho'}\Sigma_\nu G_{\nu,\rho'}K_{\nu,\lambda}+\frac{i\pi}{2}\sum_\rho\Sigma_{\lambda'}\Sigma_c m_{\lambda'}r_\rho G_{c,\rho}K_{c,\lambda'}+\tfrac{1}{2}\Sigma_\rho\Sigma_{\rho'}r_\rho r_{\rho'}\delta_{\rho,\rho'}$$

$$=\Sigma_c\epsilon_c\omega_c-i\Sigma\epsilon'_\nu\omega_\nu+i\pi\Sigma_\lambda m_\lambda r_\lambda-i\Sigma_c\epsilon'_c\omega_c-\Sigma_c\epsilon'_c\omega'_c+\tfrac{1}{2}\Sigma_\lambda r_\lambda\delta_\lambda.$$

Moreover

$$\mathrm{Al}(u_1-\overset{a}{K}_1\ldots\ldots)=\epsilon^{\Sigma\overset{a}{J}_\nu(u_\nu-\frac{1}{2}.\overset{a}{K}_\nu)}\mathrm{Al}(u_1\ldots\ldots)_a$$

$$=\epsilon^{\Sigma_\nu(m_1J_{\nu,1}+m_2J_{\nu,2}\ldots-ir_1J_{\nu,1}-ir_2J'_{\nu,2})(u_\nu-\frac{1}{2}(m_1K_{\nu,1}\ldots-r_1i.K_{\nu,1}-))}.\mathrm{Al}(u_1\ldots)_a$$

$$=\epsilon^{\Sigma_c(\epsilon_c-\epsilon'_ci)(u_c-\frac{1}{2}(\omega_c-\omega'_ci))}\mathrm{Al}(u_1\ldots\ldots)_a.$$

Combining these results we have

$$Jc(v_1-\mu_1\pi+\delta_1 i\ldots\ldots)=\epsilon^{U}.g.\epsilon^{E(u_1,u_2,u_3)}\mathrm{Al}(u_1u_2\ldots\ldots)_a,$$

where $U=-\Sigma_c\epsilon_cu_c+i\Sigma\epsilon'_cu_c-\frac{i}{2}\Sigma_cr_cv_c+\frac{1}{2}\Sigma_c\epsilon_c\omega_c-\frac{i}{2}\Sigma_c\epsilon'_c\omega_c+\frac{i\pi}{2}\Sigma_\lambda m_\lambda r_\lambda-\frac{i}{2}\Sigma_c\epsilon'_c\omega_c$

$$-\tfrac{1}{2}\Sigma\epsilon'_c\omega'_c+\tfrac{1}{4}\Sigma_\lambda r_\lambda\delta_\lambda+\Sigma\epsilon_cu_c-i\Sigma\epsilon'_cu_c-\tfrac{1}{2}\Sigma_c\epsilon_c\omega_c+\frac{i}{2}\Sigma\epsilon_c\omega'_c+\frac{i}{2}\Sigma_c\epsilon'_c\omega_c+\tfrac{1}{2}\Sigma\epsilon'_c\omega'_c.$$

Now $\qquad\Sigma_c\epsilon'_c\omega_c-\Sigma_c\epsilon_c\omega'_c=$

$$\Sigma_c\{(m_1K_{c,1}+m_2K_{c,2}+m_3K_{c,3}+\ldots\ldots)(r_1J'_{c,1}+r_2J'_{c,2}+r_3J'_{c,3}+\ldots\ldots)\}$$

$$-\Sigma_c\{(m_1J_{c,1}+m_2J_{c,2}+m_3J_{c,3}+\ldots\ldots)(r_1K'_{c,1}+r_2K'_{c,2}+r_3K'_{c,3}+\ldots\ldots)\}$$

$$=\frac{\pi}{2}(m_1r_1+m_2r_2+\ldots\ldots)=\frac{\pi}{2}\Sigma_\lambda m_\lambda r_\lambda.$$

Consequently, substituting this in the preceding formula and reducing, we shall have

$$U=-\frac{i}{2}\Sigma_\lambda r_\lambda(v_\lambda-\tfrac{1}{2}m_\lambda\pi+\tfrac{1}{2}\delta_\lambda i);\text{ and therefore}$$

$$g.\epsilon^{E(u_1,u_2,u_3\ldots\ldots u_n)}\mathrm{Al}(u_1,u_2\ldots.u_n)_a=\epsilon^{\frac{i}{2}\Sigma_\lambda r_\lambda(v_\lambda-\frac{1}{2}m_\lambda\pi+\frac{1}{2}\delta_\lambda i)}J_c(v_1-\tfrac{1}{2}m_\lambda\pi+\tfrac{1}{2}\delta_\lambda i\ldots),$$

which is the formula 60, p. 305.

Weierstrass then shows that we are able to expand $J_c(v_1-m_1\pi+\delta_1 i\ldots\ldots)$ in a series of exponentials.

Section 13.—The theorems just given contain in fact the solution of what Clebsch and Gordan have called the 'Umkehr Problem,' as applied to the hyperelliptic functions; for we have already given $al(u_1,u_2\ldots\ldots)_a=\dfrac{\mathrm{Al}(u_1u_2\ldots)_a}{\mathrm{Al}(u_1u_2\ldots)}$: but we have also shown that $\mathrm{Al}(u_1u_2\ldots\ldots)$ depends on $J_c(v_1v_2\ldots\ldots)$, where v_1, v_2

are connected linearly with $u_1 u_2$ &c., and $J_c(v_1 v_2 \ldots .)$ can be expanded in a series of exponentials. Moreover, we now see that $\mathrm{Al}(u_1 u_2 \ldots .)_\alpha$ depends on $J_c(v_1 - m_1\pi + \delta_1 i \ldots .)$, when $J_c(v_1 - m_1\pi + \delta_1 i \ldots .)$ can be expanded in a series of exponentials. Hence $al(u_1 u_2 \ldots .)_\alpha$ can be expressed as the ratio of two series of exponentials, a theorem equivalent to the well-known $\sin am \frac{2Kx}{\pi} = \frac{1}{\sqrt{k}} \frac{\theta_1 x}{\theta x}$.

Section 14.—We shall conclude this part of our subject by giving the expansion of hyperelliptic functions in terms of divided arguments as given in Dr. Weierstrass's second paper.

Let
$$R(x) = (x - a_1)(x - a_2) \ldots . (x - a_{2\rho+1}),$$

$$P(x) = (x - a_1)(x - a_2) \ldots . (x - a_\rho), \quad R(x) = P(x) Qx,$$

$$Q(x) = (x - x_1)(x - x_2) \ldots . (x - x_\rho),$$

$$du_1 = \frac{1}{2} \cdot \frac{P(x_1)}{x_1 - a_1} \cdot \frac{dx_1}{\sqrt{Rx_1}} + \frac{1}{2} \cdot \frac{P(x_2)}{x_2 - a_1} \cdot \frac{dx_2}{\sqrt{Rx_2}} + \ldots . + \frac{P(x_\rho)}{x_\rho - a_1} \cdot \frac{dx_\rho}{\sqrt{Rx_\rho}},$$

$$du_2 = \frac{1}{2} \cdot \frac{P(x_1)}{x_1 - a_2} \cdot \frac{dx_1}{\sqrt{Rx_1}} + \frac{1}{2} \cdot \frac{Px_2}{x_2 - a_2} \cdot \frac{dx_2}{\sqrt{Rx_2}} + \ldots . + \frac{Px_\rho}{x_\rho - a_2} \cdot \frac{dx_\rho}{\sqrt{Rx_\rho}},$$

$$\ldots \ldots$$

$$du_\rho = \frac{1}{2} \cdot \frac{P(x_1)}{x_1 - a_\rho} \cdot \frac{dx_1}{\sqrt{Rx_1}} + \frac{1}{2} \cdot \frac{Px_2}{x_2 - a_\rho} \cdot \frac{dx_2}{\sqrt{Rx_2}} + \ldots . + \frac{Px_\rho}{x_\rho - a_\rho} \cdot \frac{dx_\rho}{\sqrt{Rx_\rho}}.$$

Any one of these equations may be written $\Sigma \frac{1}{2} \cdot \frac{Px_\mu}{x_\mu - a_\nu} \cdot \frac{dx_\mu}{\sqrt{Rx_\mu}} = du_\nu$, where Σ applies to μ, and extends from 1 to ρ.

Now let $x_1', x_2' \ldots . x_\rho', x_1'', x_2'' \ldots . x_\rho'' \ldots . x_1^{(m)}, x_2^{(m)} \ldots . x_\rho^{(m)}$ be a set of $m\rho$ variables corresponding to the arguments $u_1', u_2' \ldots . u_\rho', u_1'', u_2'' \ldots . u_\rho'', u_1^{(m)}, u_2^{(m)} \ldots . u_\rho^{(m)}$ (m being an even number), so that

$$\Sigma \frac{1}{2} \cdot \frac{Px_\mu'}{x_\mu' - a_1} \cdot \frac{dx_\mu'}{\sqrt{Rx_\mu'}} = du_1', \quad \Sigma \frac{1}{2} \cdot \frac{Px_\mu''}{x_\mu'' - a_1} \cdot \frac{dx_\mu''}{\sqrt{Rx_\mu''}} = du_1'' \ldots .,$$

$$\Sigma \frac{1}{2} \cdot \frac{Px_\mu^{(m)}}{x_\mu^{(m)} - a_1} \cdot \frac{dx_\mu^{(m)}}{\sqrt{Rx_\mu^{(m)}}} = du_1^{(m)},$$

$$\Sigma \frac{1}{2} \cdot \frac{Px_\mu'}{x_\mu' - a_2} \cdot \frac{dx_\mu'}{\sqrt{Rx_\mu'}} = du_2', \quad \Sigma \frac{1}{2} \cdot \frac{Px_\mu''}{x_\mu'' - a_2} \cdot \frac{dx_\mu''}{\sqrt{Rx_\mu''}} = du_2'' \ldots .,$$

$$\Sigma \frac{1}{2} \cdot \frac{Px_\mu^{(m)}}{x_\mu^{(m)} - a_2} \cdot \frac{dx_\mu^{(m)}}{\sqrt{Rx_\mu^{(m)}}} = du_2^{(m)},$$

&c. = &c.,

$$\Sigma\frac{1}{2}\cdot\frac{Px'_\mu}{x'_\mu-a_\rho}\cdot\frac{dx'_\mu}{\sqrt{Rx'_\mu}}=du'_\rho,\quad \Sigma\frac{1}{2}\cdot\frac{Px''_\mu}{x''_\mu-a_\rho}=du''_\rho\ldots,$$

$$\Sigma\frac{1}{2}\cdot\frac{Px^{(m)}_\mu}{x^{(m)}_\mu-a_\rho}\cdot\frac{dx^{(m)}}{\sqrt{Rx^{(m)}_\mu}}=du^{(m)}_\rho;$$

also let $M(x)$ be a rational and entire function of the $\left(\frac{m\rho}{2}\right)$th, $N(x)$ one of the $\left(\frac{m\rho}{2}-1\right)$th order; also let

$$P(x)M^2(x)-Q(x)N^2(x)=\Pi(x)\phi(x),\text{ where}$$

$$\Pi(x)=(x-x'_1)\ldots,(x-x'_\rho),(x-x''_\rho)\ldots,(x-x''_\rho),$$

$$\ldots(x-x^{(m)}_\rho)\ldots(x-x^{(m)}_\rho),$$

we consequently have for $\phi(a_\nu)$, where a_ν is one of the roots of $P(x)=0$, $\phi(a_\nu)=-\frac{Q(a_\nu)N^2(a_\nu)}{\Pi(a_\nu)}$. Weierstrass has shown that it is possible to determine x'_1, x''_1, x'_2, x''_2, &c. from the hyperelliptic differential equations by reversion of series, and that consequently in terms of u'_1, u'_2, $u''_1\ldots$ $-\frac{\phi(a_\nu)}{Q(a_\nu)}$ may be expressed by a series $f(u'_1..u^{(m)}_1,\ u''_2..u^{(m)}_2,\ u'_\rho..u^{(m)}_\rho)$.

But, by Abel's theorem,

$$u_1=u'_1+u''_1+\ldots+u^{(m)}_1,$$

$$u_2=u'_2+u''_2+\ldots+u^{(m)}_2,$$

$$\&\text{c.}=\ldots.$$

$$u_\rho=u'_\rho+u''_\rho+\ldots+u^{(m)}_\rho.$$

Now let

$$u'_1=u''_1=\ldots=u^{(\mu)}_1=\frac{u_1}{m},$$

$$u'_2=u''_2=\ldots=u^{(\mu)}_2=\frac{u_2}{m},$$

$$\&\text{c.}=\ldots.$$

$$u'_\rho=u'_\rho=\ldots=u^{(\mu)}_\rho=\frac{u_\rho}{m};$$

whence the expression for $-\frac{\phi(a_\nu)}{Q(a_\nu)}$ will become $F\left(\frac{u_1}{\mu},\frac{u_2}{\mu}\ldots,\frac{u_\rho}{\mu}\right)$, or, other words, the arguments may be taken as small as we please.

Report of the Committee appointed for the purpose of promoting the extension, improvement, and harmonic analysis of Tidal Observations. Consisting of Sir WILLIAM THOMSON, *LL.D., F.R.S.,* Prof. J. C. ADAMS, *F.R.S.,* J. OLDHAM, WILLIAM PARKES, *M.Inst.C.E.,* Prof. RANKINE, *LL.D., F.R.S.,* and Admiral RICHARDS, *R.N., F.R.S.*

Drawn up by Mr. E. Roberts, under direction of the Committee.

1. THE results already deduced from the discussion of tidal observations by the method of *harmonic analysis* being scattered through several successive reports, it has been thought highly desirable to collect and rearrange them in the present Report for comparison and facility of reference, along with the results obtained during the past year. A full description of the method pursued in the reduction of the observations is first given in order that the results may be more readily understood. The explanation is the same generally as that contained in the Committee's first Report; additions and alterations have, however, been made where found necessary during the reduction of the observations.

2. The chief, it may be almost said the only, practical conclusion deducible from, or at least hitherto deduced from, the dynamical theory is, that the height of the water at any place may be expressed as the sum of a number of simple harmonic functions* of the time, of which the periods are known, being the periods of certain components of the sun's and moon's motions†. Any such harmonic term will be called a tidal constituent, or sometimes, for brevity, a tide. The expression for it in ordinary analytical notation is $A\cos nt + B\sin nt$; or $R\cos(nt-\epsilon)$, if $A=R\cos\epsilon$ and $B=R\sin\epsilon$; where t denotes time measured in any unit from any era, n the corresponding angular velocity, the *speed*, as it will henceforth be called for brevity (a quantity such that $\frac{2\pi}{n}$ is the period of the function), R and ϵ the amplitude and the epoch, and A and B coefficients immediately determined from observation by the proper harmonic analysis (which consists virtually in the method of least squares applied to deduce the most probable values of these coefficients from the observations).

3. The chief tidal constituents in the North Atlantic Ocean, indeed in all localities where the tides are comparatively well known, are those whose periods are twelve mean lunar hours and twelve mean solar hours respectively. Those which stand next in importance are the tides whose periods are approximately twenty-four hours. The former are called the lunar semidiurnal tide and solar semidiurnal tide; the latter, the lunar diurnal tide and the solar diurnal tide‡. There are, besides, the lunar fortnightly tide and the solar semiannual tide§. The diurnal and the semidiurnal tides have inequalities depending on the excentricity of the moon's orbit round the earth, and of the earth's round the sun, and the semidiurnal have inequalities depending on the varying declinations of the two bodies. Each such inequality of any one of the chief tides may be regarded as a smaller superimposed tide of approximately equal period, producing with the chief

* See Thomson and Tait's 'Natural Philosophy,' §§ 53, 54.

† See Laplace, 'Mécanique Céleste,' liv. iv. § 16. Airy's 'Tides and Waves,' § 585.

‡ See Airy's 'Tides and Waves,' §§ 46, 49; or Thomson and Tait's 'Natural Philosophy,' § 808.

§ See Airy's 'Tides and Waves,' § 45; or Thomson and Tait's 'Natural Philosophy,' § 880.

tide a compound effect which corresponds precisely to the discord of two simple harmonic notes in music approximately in unison with one another. These constituents may be called, for brevity, elliptic and declinational tides. Thus we have the following schedule of tidal constituents:—

		Speeds. Lunar.	Speeds. Solar.
The lunar monthly and solar annual (elliptic).	2	$\sigma-\varpi$	η
The lunar fortnightly and solar semiannual (declinational)	2	2σ	2η
The lunar and solar diurnal (declinational) .	4	$\begin{cases}\gamma\\ \gamma-2\sigma\end{cases}$	$\begin{cases}\gamma\\ \gamma-2\eta\end{cases}$
The lunar and solar semidiurnal	2	$2(\gamma-\sigma)$	$2(\gamma-\eta)$
The lunar and solar elliptic diurnal . . .	7	$\begin{cases}\gamma+\sigma-\varpi\\ \gamma-\sigma+\varpi\\ \gamma-\sigma-\varpi\\ \gamma-3\sigma+\varpi\end{cases}$	$\begin{cases}\gamma+\eta\\ \gamma-\eta\\ \gamma-\eta\\ \gamma-3\eta\end{cases}$
The lunar and solar elliptic semidiurnal . .	4	$\begin{cases}2\gamma-\sigma-\varpi\\ 2\gamma-3\sigma+\varpi\end{cases}$	$\begin{cases}2\gamma-\eta\\ 2\gamma-3\eta\end{cases}$
The lunar and solar declinational semidiurnal	2	2γ	2γ

4. Here γ denotes the angular velocity of the earth's rotation, and σ, η, ϖ those of the moon's revolution round the earth, of the earth's round the sun, and of the progression of the moon's perigee. The motion of the first point of Aries and of the earth's perihelion are neglected. The slow *variation* of the lunar declinational tides due to the retrogression of the nodes of the moon's orbit may be dealt with, probably with sufficient accuracy, according to the equilibrium method. The inequalities produced by perturbations of the moon's motion, other than of *evection* and *variation*, are insensible. These perturbations give tidal constituents, which must be included in the analysis for all places at which the range of tide is considerable. The following are the speeds of these perturbing elements for semidiurnal tides:—

Lunar *evection* semidiurnal . . . $\begin{cases}2\gamma-\sigma+\varpi-2\eta\\ 2\gamma-3\sigma-\varpi+2\eta\end{cases}$

Lunar *variation* semidiurnal . . $\begin{cases}2\gamma-4\sigma+2\eta\\ 2\gamma-2\eta\end{cases}$

There are also *evection* and *variation* diurnal tides, but which, from their nature, must be necessarily very small, and consequently have not hitherto been included in the analysis.

5. There are besides, as Laplace has shown, very sensible tides depending on the fourth power of the moon's parallax*, the investigation of which must be included in the complete analysis now suggested, although for simplicity they have been left out of the preceding schedule. The amplitude and the epoch of each tidal constituent for any part of the sea is to be determined by observation, and cannot be determined except by observation. But it is to be remarked that two of the solar elliptic diurnal tides thus indicated have the same period, being twenty-four mean solar hours, and also the period of one of the lunar diurnal tides agrees with that of one of the solar diurnal tides, being twenty-four sidereal hours, and that the period of one

[* The chief effect of this at any one station is a *terdiurnal* lunar tide, or one whose period is eight lunar hours. Values of this have been determined from the tidal observations at Liverpool, Ramsgate, Portland Breakwater, &c.]

of the semidiurnal lunar declinational tides agrees with that of one of the semidiurnal solar declinational tides, being twelve sidereal hours; also that the angular velocities $\gamma-\sigma+\varpi$ and $\gamma-\sigma-\varpi$ are so nearly equal, that observations through several consecutive years must be combined to distinguish the two corresponding elliptic diurnal tides. Again, one of the lunar *variation* tides has the same period as the chief solar semidiurnal tide. This would be of great importance for tidal theory, were it not that its magnitude must be so small as to be scarcely sensible. Each lunar declinational tide varies from a minimum to a maximum, and back to a minimum, every nineteen years or thereabouts (the period of revolution of the line of nodes of the moon's orbit). Observations continued for nineteen years will give the amount of this variation with considerable accuracy, and from it the proportion of the effect due to the moon will be distinguished from that due to the sun. It is probable that thus a somewhat accurate evaluation of the moon's mass may be arrived at.

6. There are also shallow-water tides which depend on the rise and fall of the tide, amounting to some sensible part of the whole depth of the water, or, which comes to the same, the horizontal velocity of the water being sensible in comparison with the velocity of propagation of a long wave through some considerable portion of the sea which sensibly influences the tides at the point of observation. Helmholtz's explanation of compound sounds, according to which two sounds, each a simple harmonic, having mt, nt for their arguments, give rise, if loud enough, to sounds having for their arguments $(m+n)t$, $(m-n)t$, suggests that the compound action of the solar and lunar semidiurnal tides must give rise to shallow-water tides, whose speeds are $2(\sigma-\eta)$ and $2(2\gamma-\sigma-\eta)$. The action of the solar or lunar semidiurnal tide alone must also (by the case $m=n$) give rise to shallow-water tides. The following are the speeds of these compound shallow-water tides which have (with one exception not yet tried) been found to be sensible at some of the places discussed hereafter:—

	Speeds.	
Helmholtz compound shallow-water tides	$2(\sigma-\eta)$	fortnightly.
	$2(2\gamma-\sigma-\eta)$	quarter-diurnal.
	$2\gamma-4\sigma+2\eta$	semidiurnal.
	$2\gamma+2\sigma-4\eta$	
	$2(2\gamma-3\sigma+\eta)$	quarter-diurnal.
	$2(2\gamma+\sigma-3\eta)$	

One of the semidiurnal components contained in the above list has the same period as one of the *variation* semidiurnal tides, and is therefore to be held accountable for any deviation, whether of magnitude or of epoch, which the tide of this period, calculated from observation, may show from the values which might be expected merely from the lunar perturbation alone.

7. The methods of reduction hitherto adopted*, after the example set by Laplace and Lubbock, have consisted chiefly, or altogether, in averaging the heights and times of high water and low water in certain selected sets of groups. Laplace commenced in this way, as the only one for which observations made before his time were available. How strong the tendency is to pay attention chiefly or exclusively to the times and heights of high and low water is indicated by the title printed at the top of the sheets used

* See 'Directions for reducing Tidal Observations,' by Staff-Commander Burdwood (London, 1865, published by the Admiralty); also Professor Haughton on the "Solar and Lunar Diurnal Tides on the Coast of Ireland," Transactions of the Royal Irish Academy for April 1854.

by the Admiralty to receive the automatic records of the tide-gauges; for instance, "Diagram, showing time of high and low water at Ramsgate, traced by the tide-gauge." One of the chief practical objects of tidal investigation is, of course, to predict the time and height of high water; but this object is much more easily and accurately attained by the harmonic reduction of observations not confined to high or low water. The best arrangement of observations is to make them at equidistant intervals of time, and to observe simply the height of the water at the moment of observation irrespectively of the time of high or low water. This kind of observation will even be less laborious and less wasteful of time in practice than the system of waiting for high or low water, and estimating by a troublesome interpolation the time of high water, from observations made from ten minutes to ten minutes for some time preceding it and following it. The most *complete* system of observation is, of course, that of the self-registering tide-gauge, which gives the height of the water-level above a fixed mark every instant. But direct observation and measurement would probably be more *accurate* than the records of the most perfect tide-gauge likely to be realized.

8. One object proposed for the Committee is to estimate the accuracy, both as to time and as to scale of height, attained by the best self-registering tide-gauges at present in use, and (taking into account also the relative costliness of different methods) to come to a resolution as to what method should be recommended when new sets of observations are set on foot in any place. In the mean time the following method of observation is recommended as being more accurate and probably less expensive than the plan of measurement on a stem attached to a float, often hitherto followed where there is no self-registering tide-gauge. A metal tube, which need not be more than 2 or 3 inches in diameter, is to be fixed vertically in hydrostatic communication, by its lower end, with the sea. A metal scale graduated to centimetres (or to hundredths of a foot, if preferred) is to be let down by the observer in the middle of the tube until it touches the liquid surface; and a fixed mark attached to the top of the tube then indicates the reading which is to be taken. Attached to the measuring-scale must be one or more pistons fitting loosely in the tube and guiding the rod so that it may remain, as nearly as may be, in the centre of the tube. The observer will know when its lower end is precisely at the level of the surface of the liquid, by aid of an electric circuit completed through a single galvanic cell, the coil of a common telegraph "detector," the metal measuring-scale, the liquid, and the metal tube*. By this method it will be easy to test the position of the water-level truly to the tenth of an inch. It is not probable that tidal observations hitherto made, whether with self-registering tide-gauges or by direct observations, have had this degree of accuracy; and it is quite certain that a proper method of reduction will take advantage of all the accuracy of the plan now proposed.

9. An observation made on this plan every three hours, from day to day for a month, would probably suffice to give the data required for nautical purposes for any harbour. It is intended immediately to construct an apparatus of the kind, and give it a trial for a few weeks at some convenient harbour; and if the plan prove to be successful and convenient, it will come to be considered whether observations made at every hour of the day and

[* Instead of the galvanic detector, an hydraulic method may be found preferable in some places. The latter consists in using a stiff tube of half inch diameter or so, instead of the solid metal measuring-bar, and testing whether its lower end is above or below the level of the water by suction at the upper end.]

night might not, all things considered (accuracy, economy, and sufficiency for all scientific wants), be preferable to a self-registering tide-gauge.

10. One of the most interesting of the questions that can be proposed in reference to the tides is, how much is the earth's angular velocity diminished by them from century to century? The direct determination of this amount, however, or even a rough estimate of it, can scarcely be hoped for from tidal observation, as the data for the quadrature required could not be had directly. But accurate observation of amounts and times of the tide on the shores of continents and islands of all seas might, with the assistance of improved dynamical theory, be fully expected to supply the requisite data for at least a rough estimate. In the mean time it may be remarked that one very important point of the theory, discovered by Dr. Thomas Young and independently by Airy*, affords a ready means of disentangling some of the complicacy presented by the distribution of the times of high water in different places, and will form a sure foundation for the practical estimate of a definite *part* of the whole amount of retardation, when the times of spring-tides and neap-tides are better known for all parts of the sea than they are at present. To understand this, imagine a tidal spheroid to be constructed by drawing an infinite number of lines perpendicular to the actual mean sea-level continued under the solid parts of the earth which lie above the sea-level, and equal to the spherical harmonic term or Laplace's function, of the second order, in the development of a discontinuous function equal to the height of the sea at any point above the mean level where there is sea, and equal to zero for all the rest of the earth's surface. This spheroid we shall call, for brevity, the mean tidal spheroid (lunar or solar as the case may be, or lunisolar when the heights due to moon and sun are added). The fact that the lunar semidiurnal tide is, over nearly the whole surface of the sea, greater than the solar, in a greater ratio than that of the generating force, renders it almost certain that the longest axes of the mean lunitidal and solitidal spheroids would each of them lie in the meridian 90° from the disturbing body (moon or sun) if the motion of the water were unopposed by friction; or, which means the same thing, that there would be on the average of the whole seas, *low* water when the disturbing body crosses the meridian, were the hypothesis of no friction fulfilled. But, as Airy has shown, the tendency of friction is to *advance* the times of low and high water when the depth and shape of the ocean are such as to make the time of low water, on the hypothesis of no friction, be that of the disturbing body's transit. Now the well-known fact that the spring-tides on the Atlantic coast of Europe are about a day or a day and a half after full and change (the times of greatest force), and that through nearly the whole sea they are probably more or less behind these times, which Young and Airy long ago maintained to be a consequence of friction, would prove that the crowns of the lunitidal spheroid are in advance of those of the solitidal spheroid, and therefore that those of the latter are less advanced by friction than those of the former. It is easily conceived that a knowledge of the heights of the tides and of the intervals between the spring-tides and the times of greatest force, somewhat more extensive than we have at present, would afford data for a rough estimate of the proper mean amount of the average interval in question—that is, of the interval between the times of high water of the mean lunitidal and mean solitidal spheroids. The whole moment of the couple retarding the earth's rotation, in virtue of the lunar tide, must be something more than that calcu-

* See the collected works of Dr. Thomas Young, vol. ii. No. LIV. (London, 1855, John Murray), and Airy's 'Tides and Waves,' §§ 459, 544.

lated on the hypothesis that the obliquity of the mean lunitidal spheroid is only equal to the hour-angle corresponding to that interval of time.

11. We know, however, but little at present regarding the actual time of the spring-tides in different parts of the ocean; and it is not even quite certain, although, as Airy remarks, it is extremely probable, that in the southern seas they take place at an interval *after* the full and change, although it may be at a less interval than on the Atlantic coast of Europe. There must be observations on record (such as those of Sir Thomas Maclear at the Cape of Good Hope, which Staff-Commander Burdwood showed to Sir W. Thomson in the Hydrographical Office of the Admiralty) valuable for determining this very important element for ports on all seas where any approach to a knowledge of the laws of the tides has been made.

To collect information on this point from all parts of the world will be one of the most interesting parts of the work of the Committee.

12. Another very interesting subject for inquiry is the lunar fortnightly, or solar semiannual, tide, the determination of which will form part of the complete harmonic reduction of proper observations made for a sufficient time. The amounts of these tides must be very sensible in all places remote from the zero line* of either northern or southern hemisphere, unless the solid earth yields very sensibly in its figure to the tide-generating force†. Thus it has been calculated that if the earth were perfectly rigid, the sum of the rise from lowest to highest at Teneriffe, and simultaneous fall from highest to lowest at Iceland, in the lunar fortnightly tides, would amount to 4·5 inches. The preliminary trials of plans for harmonic reduction referred to below, make it almost certain that hourly observations, continued for a sufficiently long time at two such stations as these, would determine the amount of the fortnightly tide to a fraction of an inch, and so would give immediate data for answering, to some degree of accuracy, the question how much does the solid earth really yield to the tide-generating force?

13. A beautiful synthesis of the complex dynamical action to which the semidiurnal tides are due, imagined by Laplace, will be used in this Report to enable us to avoid circumlocution. A number of ideal stars ("astres fictifs") are assumed to move, each uniformly in the plane of the earth's equator, with angular velocities small in comparison with that of the earth's rotation, so that the period of each relatively to the earth is something not very different from the lunar or solar twenty-four hours. Each one of the approximately semidiurnal tides (§ 3) is produced by one alone of these ideal stars.

14. One of the ideal stars is what is commonly called in England the "mean sun," being that point of the celestial sphere in the plane of the earth's equator whose hour-angle is equal to mean solar time: for brevity we shall call it S. Another of them might be the "mean moon" similarly defined (called M); but, to allow the same Tables (§ 16) to be used for the reduction of tidal observations of different years, we shall take it as a point moving in the plane of the earth's equator, with an angular velocity equal to the mean angular velocity of the moon, and set at $0^{\circ}\cdot 0$ for its hour-angle at the commencement of any series of observations‡.

Similarly K might be the first point of Aries, but, for the same reason, will

* Thomson and Tait's 'Natural Philosophy,' § 810.

† "On the Rigidity of the Earth," W. Thomson, Trans. R. S., May 1862; or Thomson and Tait's 'Natural Philosophy,' §§ 832–849.

‡ Other hour-angles to those here given were first used, but not proving of any practical utility, the above were substituted for them, simplifying to some extent the ultimate corrections depending on these assumptions.

be taken as a point in the plane of the earth's equator, set so that its hour-angle is $0°{\cdot}0$ at commencement.

O is an ideal whose right ascension increases twice as fast as that of the mean moon, and which is also set with $0°{\cdot}0$ for its hour-angle at commencement. L and N are ideal stars whose rates of increase of right ascension are respectively greater than, and less than, that of the mean moon, by a difference equal to half that of the mean moon relatively to her perigee.

15. General Schedule of the diurnal, semidiurnal, terdiurnal, and short-period shallow-water tides, which have been included in the analysis, showing speeds in degrees per mean solar hour, and periods in mean solar hours :—

Distinguishing Letters.	Diurnal Speeds. °	Diurnal Periods. h	Semidiurnal Speeds. °	Semidiurnal Periods. h
S	$\gamma-\eta=15{\cdot}0000000$	24·0000	$2(\gamma-\eta)=30{\cdot}0000000$	12·0000
R	....	.. ...	$2\gamma-\eta=30{\cdot}0410686$	11·9836
T	....	... .	$2\gamma-3\eta=29{\cdot}9589314$	12·0165
P	$\gamma-2\eta=14{\cdot}9589314$	24·0659	....	... ..
K	$\gamma=15{\cdot}0410686$	23·9345	$2\gamma=30{\cdot}0821372$	11·9672
M	$\gamma-\sigma=14{\cdot}4920521$	24·8412	$2(\gamma-\sigma)=28{\cdot}9841042$	12·4206
L	... .	......	$2\gamma-\sigma-\varpi=29{\cdot}5284788$	12·1916
N	....	.. ..	$2\gamma-3\sigma+\varpi=28{\cdot}4397296$	12·6584
O	$\gamma-2\sigma=13{\cdot}9430356$	25·8194		
J	$\gamma+\sigma-\varpi=15{\cdot}5854433$	23·0985	....	......
Q	$\gamma-3\sigma+\varpi=13{\cdot}3986609$	26·8684	....	......
λ	....	.. ..	$2\gamma-\sigma+\varpi-2\eta=29{\cdot}4556254$	12·2218
ν	....	.... .	$2\gamma-3\sigma-\varpi+2\eta=28\ 5125830$	12·6260
μ or 2MS	....	......	$2(\gamma-2\sigma+\eta)=27{\cdot}9682084$	12·8718
2SM	....	.... .	$2(\gamma+\sigma-2\eta)=31{\cdot}0158958$	11·6070

	Terdiurnal Speeds. °	Terdiurnal Periods. h	Quarter-diurnal (shallow-water) Speeds. °	Quarter-diurnal (shallow-water) Periods. h
S	....	......	$4(\gamma-\eta)=60{\cdot}0000000$	6·0000
M	$3(\gamma-\sigma)=43{\cdot}4761563$	8·2804	$4(\gamma-\sigma)=57{\cdot}9682084$	6·2103
MS	....	.. ...	$4(\gamma-\frac{1}{2}\sigma-\frac{1}{2}\eta)=58{\cdot}9841044$	6·1033
3MS	....	.. .	$4(\gamma-\frac{3}{2}\sigma+\frac{1}{2}\eta)=56{\cdot}9523128$	6·3211
3SM	....	.. ..	$4(\gamma+\frac{1}{2}\sigma-\frac{3}{2}\eta)=61{\cdot}0158960$	5·9001

	$\frac{1}{6}$-diurnal (shallow-water) Speeds. °	$\frac{1}{6}$-diurnal (shallow-water) Periods. h	$\frac{1}{8}$-diurnal (shallow-water) Speeds. °	$\frac{1}{8}$-diurnal (shallow-water) Periods. h
S	$6(\gamma-\eta)=90{\cdot}0000000$	4·0000	$8(\gamma-\eta)=120{\cdot}0000000$	3·0000
M	$6(\gamma-\sigma)=87{\cdot}9523126$	4·1402	$8(\gamma-\sigma)=116{\cdot}9364168$	3·1052

16. If t denote time reckoned in mean solar hours from the commencement of any set of observations,

$$\gamma t,\quad (\gamma-\tfrac{1}{2}\sigma-\tfrac{1}{2}\varpi)t,\quad (\gamma-\sigma)t,\ \&c.$$

will be the hour-angles of the ideal stars. These have been calculated by successive additions for each integral mean solar hour of the year, and subtraction of 360 every time a number exceeding 360 has been reached; and the results have been tabulated. Preceding each hour-angle, the number which, multiplied by 15, most nearly agrees with it has been written. The following is a specimen page for one day of the Table thus formed:—

S		R		T		P		K	
$(\gamma-\eta)t$		$(\gamma-\frac{1}{2}\eta)t$		$(\gamma-\frac{3}{2}\eta)t$		$(\gamma-2\eta)t$		γt	
h	°	h	°	h	°	h	°	h	°
0	0	0	0·00	0	0·00	0	0·00	0	0·00
1	15	1	15·02	1	14·98	1	14·96	1	15·04
2	30	2	30·04	2	29·96	2	29·92	2	30·08
3	45	3	45·06	3	44·94	3	44·88	3	45·12
4	60	4	60·08	4	59·92	4	59·84	4	60·16
5	75	5	75·11	5	74·90	5	74·79	5	75·21
6	90	6	90·13	6	89·88	6	89·75	6	90·25
7	105	7	105·15	7	104·85	7	104 71	7	105·29
8	120	8	120·17	8	119·83	8	119·67	8	120·33
9	135	9	135·19	9	134·81	9	134·63	9	135·37
10	150	10	150 21	10	149·79	10	149·59	10	150·41
11	165	11	165·23	11	164·77	11	164·55	11	165·45
12	180	12	180·25	12	179·75	12	179·51	12	180·49
13	195	13	195·27	13	194·73	13	194·47	13	195·53
14	210	14	210·29	14	209·71	14	209·42	14	210·57
15	225	15	225·32	15	224·69	15	224·38	15	225·62
16	240	16	240·34	16	239·66	16	239·34	16	240·66
17	255	17	255·36	17	254·64	17	254·30	17	255·70
18	270	18	270·38	18	269 62	18	269·26	18	270 74
19	285	19	285·40	19	284·60	19	284·22	19	285·78
20	300	20	300·42	20	299·58	20	299·18	20	300 82
21	315	21	315·44	21	314·56	21	314·14	21	315·86
22	330	22	330·46	22	329·54	22	329·10	22	330·90
23	345	23	345·48	23	344·52	23	344·05	23	345·94

S		M		L		N		O	
$(\gamma-\eta)t$		$(\gamma-\sigma)t$		$(\gamma-\frac{1}{2}\sigma-\frac{1}{2}\varpi)t$		$(\gamma-\frac{3}{2}\sigma+\frac{1}{2}\varpi)t$		$(\gamma-2\sigma)t$	
h	°	h	°	h	°	h	°	h	°
0	0	0	0·00	0	0·00	0	0·00	0	0·00
1	15	1	14·49	1	14·76	1	14·22	1	13·94
2	30	2	28·98	2	29·53	2	28·44	2	27·89
3	45	3	43·48	3	44·29	3	42·66	3	41·83
4	60	4	57·97	4	59·06	4	56 88	4	55·77
5	75	5	72·46	5	73·82	5	71·10	5	69·72
6	90	6	86·95	6	88·59	6	85·32	6	83·66
7	105	7	101·44	7	103·35	7	99·54	7	97·60
8	120	8	115·94	8	118·11	8	113·76	7	111·54
9	135	9	130·43	9	132·88	9	127·98	8	125·49
10	150	10	144·92	10	147·64	9	142 20	9	139·43
11	165	11	159·41	11	162·41	10	156 42	10	153·37
12	180	12	173·90	12	177·17	11	170·64	11	167·32
13	195	13	188·40	13	191·94	12	184·86	12	181·26
14	210	14	202·89	14	206·70	13	199·08	13	195·20
15	225	14	217·38	15	221·46	14	213·30	14	209·15
16	240	15	231·87	16	236·23	15	227 52	15	223·09
17	255	16	246·36	17	250·99	16	241·74	16	237·03
18	270	17	260·86	18	265·76	17	255·96	17	250·97
19	285	18	275·35	19	280·52	18	270·18	18	264·92
20	300	19	289·84	20	295·28	19	284·40	19	278·86
21	315	20	304·33	21	310·05	20	298·62	20	292·80
22	330	21	318·83	22	324·81	21	312·84	20	306·75
23	345	22	333·32	23	339·58	22	327·06	21	320·69

S		J		Q		λ	
$(\gamma-\eta)t$		$(\gamma+\sigma-\varpi)t$		$(\gamma-3\sigma+\varpi)t$		$(\gamma-\frac{1}{2}\sigma+\frac{1}{2}\varpi-\eta)t$	
h	°	h	°	h	°	h	°
0	0	0	0·00	0	0·00	0	0·00
1	15	1	15·59	1	13·40	1	14·73
2	30	2	31·17	2	26·80	2	29·46
3	45	3	46·76	3	40·20	3	44·18
4	60	4	62·34	4	53·59	4	58·91
5	75	5	77·93	4	66·99	5	73·64
6	90	6	93·51	5	80·39	6	88·37
7	105	7	109·10	6	93·79	7	103·09
8	120	8	124·68	7	107·19	8	117·82
9	135	9	140·27	8	120·59	9	132·55
10	150	10	155·85	9	133·99	10	147·28
11	165	11	171·44	10	147·39	11	162·01
12	180	12	187·03	11	160·78	12	176·73
13	195	14	202·61	12	174·18	13	191·46
14	210	15	218·20	13	187·58	14	206·19
15	225	16	233·78	13	200·98	15	220·92
16	240	17	249·37	14	214·38	16	235·65
17	255	18	264·95	15	227·78	17	250·37
18	270	19	280·54	16	241·18	18	265·10
19	285	20	296·12	17	254·57	19	279·83
20	300	21	311·71	18	267·97	20	294·56
21	315	22	327·29	19	281·37	21	309·28
22	330	23	342·88	20	294·77	22	324·01
23	345	0	358·47	21	308·17	23	338·74

S		ν		μ or 2MS		MS	
$(\gamma-\eta)t$		$(\gamma-\frac{3}{2}\sigma-\frac{1}{2}\varpi+\eta)t$		$(\gamma-2\sigma+\eta)t$		$(\gamma-\frac{1}{2}\sigma-\frac{1}{2}\eta)t$	
h	°	h	°	h	°	h	°
0	0	0	0·00	0	0·00	0	0·00
1	15	1	14·26	1	13·98	1	14·75
2	30	2	28·51	2	27·97	2	29·49
3	45	3	42·77	3	41·95	3	44·24
4	60	4	57·03	4	55·94	4	58·98
5	75	5	71·28	5	69·92	5	73·73
6	90	6	85·54	6	83·90	6	88·48
7	105	7	99·79	7	97·89	7	103·22
8	120	8	114·05	7	111·87	8	117·97
9	135	9	128·31	8	125·86	9	132·71
10	150	10	142·56	9	139·84	10	147·46
11	165	10	156·82	10	153·83	11	162·21
12	180	11	171·08	11	167·81	12	176·95
13	195	12	185·33	12	181·79	13	191·70
14	210	13	199·59	13	195·78	14	206·44
15	225	14	213·84	14	209·76	15	221·19
16	240	15	228·10	15	223·75	16	235·94
17	255	16	242·36	16	237·73	17	250·68
18	270	17	256·61	17	251·71	18	265·43
19	285	18	270·87	18	265·70	19	280·17
20	300	19	285·13	19	279·68	20	294·92
21	315	20	299·38	20	293·67	21	309·67
22	330	21	313·64	21	307·65	22	324·41
23	345	22	327·90	21	321·63	23	339·16

S		2SM		3MS		3SM	
$(\gamma-\eta)t$		$(\gamma+\sigma-2\eta)t$		$(\gamma-\frac{1}{2}\sigma+\frac{1}{2}\eta)t$		$(\gamma+\frac{1}{2}\sigma-\frac{1}{2}\eta)t$	
h	°	h	°	h	°	h	°
0	0	0	0·00	0	0·00	0	0·00
1	15	1	15·51	1	14·24	1	15·25
2	30	2	31·02	2	28·48	2	30·51
3	45	3	46·52	3	42·71	3	45·76
4	60	4	62·03	4	56·95	4	61·02
5	75	5	77·54	5	71·19	5	76·27
6	90	6	93·05	6	85·43	6	91·52
7	105	7	108·56	7	99·67	7	106·78
8	120	8	124·06	8	113·90	8	122·03
9	135	9	139·57	9	128·14	9	137·29
10	150	10	155·08	9	142·38	10	152·54
11	165	11	170·59	10	156·62	11	167·79
12	180	12	186·10	11	170·86	12	183·05
13	195	13	201·60	12	185·09	13	198·30
14	210	14	217·11	13	199·33	14	213·56
15	225	16	232·62	14	213·57	15	228·81
16	240	17	248·13	15	227·81	16	244·06
17	255	18	263·63	16	242·05	17	259·32
18	270	19	279·14	17	256·29	18	274·57
19	285	20	294·65	18	270·52	19	289·83
20	300	21	310·16	19	284·76	20	305·08
21	315	22	325·67	20	299·00	21	320·33
22	330	23	341·17	21	313·24	22	335·59
23	345	0	356·68	22	327·48	23	350·84

17. We will now describe the method of reduction pursued, in the first place confining ourselves to the statement of what was actually done for the year 1864 and the harbour of Ramsgate.

A datum-line 10 feet below the previously supposed mean level was chosen*, and the height of the curves marked by the self-registering tide-gauge was measured from this datum-line in feet and decimals of a foot for each integral mean solar hour of the year, and entered in the Table. A period of 369^{d} 3^{h}, or rather more than a year, was taken as being to the nearest hour twelve and a half lunations or twenty-five periods of spring- and neap-tides, and therefore giving a least possible amount of influence of the mean lunar and solar semidiurnal tides, each on the sets of averages used in the calculation of the other.

This period has been used for the evaluation of the whole of the remaining short-period tide-components contained in the previous schedule, with the exception of the elliptic diurnal and semidiurnal tides, for which the following periods were chosen for similar reasons:—

Lunar elliptic semidiurnal tides (L and N) 358^{d} 6^{h}.
Lunar *evection* semidiurnal tides (λ and ν) 349^{d} 22^{h}.
Lunar elliptic diurnal tides (J and Q) 370^{d} 5^{h}.

18. These averages were taken according to the following rule:—First for the S tides, twenty-four means of the heights at 0^{h}, 1^{h}, 2^{h}, ... 23^{h} of S hours (or ordinary mean solar time) were taken. Next for the M tides, twenty-four averages were taken of heights grouped similarly according to the M hours. In thus averaging for the M tides every height which was recorded at a time within half an M hour before or after 0^{h} M time was taken as if it had been observed at 0^{h} M time, and so for 1^{h}, 2^{h}, 3^{h}, &c. of the M time. The proper correction on this was applied afterwards, as will be described later

* The true mean level for the year 1864 was found to be 10·192 above this datum-line, or ·192 of a foot higher than was supposed.

(§ 24). Other averagings were performed according to the same rule for the K, L, N, &c. reckonings respectively each averaging giving a group of twenty-four means.

19. The next step was to find for each of these sets of averages the coefficients A_0, A_1, B_1, A_2, B_2, &c. of the harmonic formulæ,

$$\begin{aligned} A_0 + A_1 \cos\ & nt + B_1 \sin\ nt \\ + A_2 \cos\ & 2nt + B_2 \sin 2nt \\ & \cdots\cdots\cdots \\ & \cdots\cdots\cdots \\ + A_8 \cos\ & 8nt + B_8 \sin 8nt, \end{aligned}$$

n denoting, as in § 2, the rate of increase of the hour-angle for each case ; for instance γ for the K tides, $\gamma - \sigma$ for the M tides, and so on. The condition to be fulfilled is that the values of this formula calculated for $t=0$, $t=1$ . . , $t=23$ may agree as nearly as possible, on the whole, with the twenty-four numbers of the group (the sum of the squares of the differences to be a minimum*). The tabular forms and rules given by Mr. Archibald Smith, and published by the Admiralty, for the harmonic reduction of the deviation of ships' compasses, have been adopted *mutatis mutandis*, and have proved very convenient.

20. If, instead of including only seventeen coefficients, A_0, A_1, B_1, ... A_8, B_8, the calculation had been extended to A_{11}, B_{11}, A_{12}, so as to include in all twenty-four coefficients, the calculated values would necessarily have agreed with the twenty-four numbers given by observation. But there was no apparent probability that any thing more than accidental irregularities and errors of observation could be represented by higher terms than A_4, B_4, and therefore these were the highest included. The following Table exhibits the results of this process for six series, the remaining series presenting similar features. The columns headed " differences " preserve the residues, however, and may be referred to should further study of the subject indicate that useful results are to be derived from them. The greatest of them is ·055 of a foot, and the maxima in each column are only from $\frac{1}{80}$ to $\frac{1}{20}$ of a foot.

Values of A_1, B_1, A_2, &c., to first Approximation.

	S	K	L	M	N	O
	$(\gamma-\eta)$	(γ)	$(\gamma-\frac{1}{2}\sigma-\frac{1}{2}\varpi)$	$(\gamma-\sigma)$	$(\gamma-\frac{3}{2}\sigma+\frac{1}{2}\varpi)$	$(\gamma-2\sigma)$
A_1	+0·0231	−0·2052	−0·0305	+0·0223	+0·0181	−0·2963
B_1	−0·0255	−0·0236	−0·0120	−0·0058	+0·0048	+0·0687
A_2	+1·5598	−0·4540	−0·2276	−4·3176	+0·8191	−0·0904
B_2	+0·9923	−0·0061	+0·2669	+4·5037	−0·7342	−0·0007
A_3	+0·0086	+0·0037	−0·0096	−0·0138	−0·0008	−0·0073
B_3	+0·0004	+0·0015	+0·0093	+0·0408	+0·0111	+0·0078
A_4	+0·0295	−0·0127	−0·0457	−0·5443	−0·0094	+0·0030
B_4	+0·0009	−0·0021	−0·0927	−0·0878	−0·0122	+0·0034
A_5	0·0000	−0·0051	−0·0023	+0·0032	−0·0013	+0·0022
B_5	+0·0029	+0·0072	+0·0046	+0·0019	+0·0052	−0·0074
A_6	+0·0017	−0·0008	−0·0050	−0·1132	−0·0287	−0·0062
B_6	+0·0068	+0·0027	−0·0079	−0·1114	−0·0024	+0·0040
A_7	+0·0008	+0·0030	−0·0056	+0·0021	−0·0022	+0·0202
B_7	+0·0046	−0·0011	+0·0043	−0·0031	−0·0004	−0·0084
A_8	+0·0011	+0·0058	−0·0421	+0·0295	+0·0048	−0·0057
B_8	+0·0028	−0·0033	+0·0312	−0·0416	−0·0001	+0·0073
A_0	10·1988	10·1989	10·1843	10·1992	10·1853	10·1971

* According to Laplace's method of " least squares."

$(\gamma-\eta)$		
Calculated. (1)	Observed. (2)	Difference. (1)−(2)
11·8234	11·8231	+0·0003
12·0992	12·0976	+0·0016
11·8255	11·8226	+0·0029
11·1414	11·1528	−0·0114
10·2454	10·2413	+0·0041
9·3442	9·3386	+0·0056
8·6403	8·6455	−0·0052
8·3404	8·3371	+0·0033
8·5202	8·5184	+0·0018
9·1488	9·1539	−0·0051
10·0677	10·0731	−0·0054
11·0364	11·0268	+0·0096
11·7584	11·7593	−0·0009
12·0408	12·0420	−0·0012
11·8133	11·8154	−0·0021
11·1660	11·1607	+0·0053
10·2798	10·2897	−0·0099
9·3918	9·3870	+0·0048
8·6955	8·6889	+0·0066
8·3844	8·3886	−0·0042
8·5682	8·5701	−0·0019
9·2166	9·2153	+0·0013
10·1327	10·1360	−0·0033
11·0908	11·0874	+0·0034

(γ)		
Calculated. (1)	Observed. (2)	Difference. (1)−(2)
9·5336	9·5384	−0·0048
9·5944	9·5886	+0·0058
9·7901	9·7940	−0·0039
10·0467	10·0470	−0·0003
10·2872	10·2825	+0·0047
10·5013	10·5077	−0·0064
10·6300	10·6250	+0·0050
10·6197	10·6209	−0·0012
10·5148	10·5167	−0·0019
10·3483	10·3443	+0·0040
10·1501	10·1538	−0·0037
10·0000	9·9977	+0·0023
9·9408	9·9431	−0·0023
9·9882	9·9840	+0·0042
10·1539	10·1621	−0·0082
10·3705	10·3586	+0·0119
10·5572	10·5702	−0·0130
10·6729	10·6626	+0·0103
10·6636	10·6673	−0·0037
10·5373	10·5408	−0·0035
10·3552	10·3461	+0·0091
10·1041	10·1140	−0·0099
9·8107	9·8042	+0·0065
9·6030	9·6034	−0·0004

$(\gamma-\frac{1}{2}\sigma-\frac{1}{2}\varpi)$		
Calculated. (1)	Observed. (2)	Difference. (1)−(2)
9·8159	9·8165	−0·0006
10·0343	10·0483	−0·0140
10·2272	10·2018	+0·0254
10·4373	10·4650	−0·0277
10·6552	10·6342	+0·0210
10·5447	10·5549	−0·0102
10·3081	10·3057	+0·0024
10·1817	10·1864	−0·0047
9·9976	9·9850	+0·0126
9·9221	9·9460	−0·0239
10·0186	9·9894	+0·0292
9·9607	9·9846	−0·0239
9·9119	9·9033	+0·0086
10·0811	10·0704	+0·0107
10·2596	10·2839	−0·0243
10·4881	10·4609	+0·0272
10·6960	10·7134	−0·0174
10·5723	10·5700	+0·0023
10·3501	10·3393	+0·0108
10·2197	10·2332	−0·0135
9·9996	9·9912	+0·0084
9·9041	9·9010	+0·0031
9·9726	9·9838	−0·0112
9·8655	9·8549	+0·0106

$(\gamma-\sigma)$		
Calculated. (1)	Observed. (2)	Difference. (1)−(2)
5·2674	5·2795	−0·0121
8·2397	8·2397	0·0000
12·3265	12·3143	+0·0122
15·4386	15·4591	−0·0205
16·4609	16·4382	+0·0227
15·8858	15·9041	−0·0183
14·0736	14·0634	+0·0102
11·3474	11·3496	−0·0022
8·5247	8·5289	−0·0042
6·1588	6·1519	+0·0069
4·5765	4·5841	−0·0076
4·1587	4·1516	+0·0071
5·2398	5·2461	−0·0063
8·1633	8·1588	+0·0045
12·2161	12·2178	−0·0017
15·3376	15·3410	−0·0034
16·4241	16·4160	+0·0081
15·9220	15·9342	−0·0122
14·1568	14·1451	+0·0117
11·4504	11·4566	−0·0062
8·5987	8·6019	−0·0032
6·1570	6·1441	+0·0129
4·5249	4·5446	−0·0197
4·1303	4·1112	+0·0191

$(\gamma-\frac{3}{2}\sigma+\frac{1}{2}\varpi)$			$(\gamma-2\sigma)$		
Calculated. (1)	Observed. (2)	Difference. (1)−(2)	Calculated. (1)	Observed. (2)	Difference. (1)−(2)
10·9849	10·9688	+0·0161	9·8166	9·8427	−0·0261
10·5382	10·5528	−0·0146	9·8354	9·8278	+0·0076
10·0146	10·0059	+0·0087	9·9348	9·9300	+0·0048
9·4882	9·4898	−0·0016	10·0573	10·0630	−0·0057
9·1314	9·1350	−0·0036	10·1567	10·1549	+0·0018
9·1141	9·1095	+0·0046	10·2547	10·2565	−0·0018
9·3896	9·3920	−0·0024	10·3529	10·3448	+0·0081
9·8195	9·8203	−0·0008	10·4185	10·4312	−0·0127
10·3658	10·3630	+0·0028	10·4357	10·4260	+0·0097
10·9264	10·9284	−0·0020	10·4499	10·4515	−0·0016
11·2698	11·2707	−0·0009	10·4696	10·4704	−0·0008
11·2642	11·2602	+0·0040	10·4270	10·4348	−0·0078
10·9573	10·9627	−0·0054	10·3790	10·3569	+0·0221
10·4766	10·4723	+0·0043	10·4114	10·4368	−0·0254
9·9446	9·9460	−0·0014	10·4014	10·3937	+0·0077
9·4472	9·4479	−0·0007	10·3101	10·2850	+0·0251
9·1166	9·1163	+0·0003	10·2987	10·3500	−0·0513
9·1059	9·1028	+0·0031	10·3189	10·2643	+0·0546
9·3910	9·3987	−0·0077	10·2291	10·2642	−0·0351
9·8357	9·8248	+0·0109	10·1271	10·1163	+0·0108
10·3834	10·3934	−0·0100	10·0589	10·0606	−0·0017
10·9362	10·9320	+0·0042	9·9363	9·9238	+0·0125
11·2746	11·2701	+0·0045	9·8322	9·8620	−0·0298
11·2714	11·2833	−0·0119	9·8190	9·7823	+0·0367

21. In the averages for any one of the S, K, L, M, N, O, &c. tides explained above, the influence of each of the others is nearly eliminated because of the greatness of the number of periods (roughly 360 and 720) of each in the series of observed heights included in the summations. The choice of the approximate period $369^d\ 3^h$, as explained above (§ 17), makes as little as

TABLE OF COMPARATIVE MEAN SOLAR AND MEAN LUNAR HOURS.

Hour S $(\gamma-\eta)$.	Hour M $(\gamma-\sigma)$. 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
0	16	14	16	13	16	14	17	15	16	16	16	17	15	17	15	17	15	17	14	16	14	15	15	14
1	15	15	15	15	14	15	15	16	15	17	15	17	16	16	16	16	16	16	16	14	16	14	16	14
2	13	16	14	15	15	14	16	14	16	15	17	15	17	15	17	15	16	17	15	17	14	16	14	16
3	15	14	15	14	16	14	15	15	15	16	15	16	16	16	16	16	15	17	16	16	16	15	16	14
4	14	16	13	16	14	16	13	16	14	16	15	15	17	15	17	15	17	15	17	15	17	15	16	15
5	15	15	15	14	16	14	15	14	15	15	15	15	16	16	16	17	15	17	15	16	16	16	15	16
6	16	14	16	14	15	15	14	16	13	16	14	16	14	17	15	17	16	16	16	15	17	15	17	15
7	15	16	14	15	14	15	15	15	15	14	16	14	16	14	16	16	16	16	16	16	16	17	15	17
8	16	15	16	14	16	13	16	14	16	14	15	15	15	15	14	17	15	17	15	17	15	17	16	16
9	16	16	16	16	14	16	13	16	14	15	14	15	15	15	15	15	17	15	17	15	17	15	16	16
10	15	17	15	17	15	15	15	14	15	14	16	13	16	14	16	14	16	16	16	16	15	17	15	17
11	17	15	17	15	17	14	15	15	14	16	14	16	13	16	14	16	13	16	16	16	17	15	17	15
12	16	16	16	16	15	17	14	16	14	15	15	15	15	14	15	15	15	13	17	15	17	16	16	16
13	15	16	17	15	17	15	17	14	16	13	16	14	15	15	14	16	14	16	13	17	15	17	15	17
14	17	15	17	16	16	16	16	16	15	15	14	15	14	16	14	15	15	15	15	14	16	16	16	15
15	15	17	15	17	15	17	15	16	17	14	16	13	16	14	16	13	16	14	16	14	14	17	15	17
16	17	15	17	15	16	16	16	15	17	16	15	15	14	16	14	15	14	15	14	16	14	15	16	16
17	17	16	15	17	15	17	15	17	15	17	15	16	14	15	15	14	16	13	16	14	16	13	16	15
18	16	16	16	16	16	16	17	15	17	15	16	16	15	14	15	15	15	15	14	16	14	16	13	15
19	16	15	17	15	17	15	17	16	16	16	15	17	15	16	13	16	14	16	14	15	15	14	16	13
20	14	16	15	17	15	16	16	16	16	16	16	16	17	15	16	13	16	14	15	14	15	15	15	15
21	14	15	15	16	16	15	17	15	17	15	17	15	17	16	16	15	14	15	14	16	13	16	14	16
22	16	13	15	15	16	17	15	17	15	17	15	17	15	16	16	16	15	14	16	14	16	13	16	14
23	14	16	13	16	14	17	16	16	16	16	16	16	16	15	17	15	17	15	15	15	15	15	14	15

possible of the mutual influence of the two largest tides, the lunar and solar semidiurnal tides, in the two averagings performed to determine these two tides. But the incommensurability of the periods renders it impossible to altogether escape, in the direct synthesis for any one tide, the influence of the others. Accordingly, the coefficients A_1, B_1, &c., shown above, are to be regarded as first approximations in the mathematical solution of the problem. The next step followed was to find corrections upon each summation for the influence of the tides determined by the other summations, these corrections, for a second approximation, being calculated on the supposition that the first approximate values of A_1, B_1, A_2, &c., already found, are correct. Auxiliary Tables for performing this process have been formed for use along with the other Tables (one being given as a specimen, p. 367); but the ultimate corrections found from them, after very considerable labour, affected the terms which represent genuine tide-components in so small a degree that their use has since been discontinued. The S, K, L, M, N, and O tides for Ramsgate, 1864, were, however, so corrected, and the corrections thus formed are here given.

22. The corrections are to be subtracted from the values of A_1, B_1, A_2, &c., to first approximation, and are as follow:—

Table of Corrections of the 6 × 16 Coefficients A_1, B_1, &c.

	S	K	L	M	N	O
	$(\gamma-\eta)$	(γ)	$(\gamma-\frac{1}{2}\sigma-\frac{1}{2}\varpi)$	$(\gamma-\sigma)$	$(\gamma-\frac{3}{2}\sigma+\frac{1}{2}\varpi)$	$(\gamma-2\sigma)$
A_1	−·0025	−·0002	−·0021	+·0087	−·0151	−·0032
B_1	+·0015	+·0001	−·0050	−·0003	+·0032	+·0056
A_2	−·0018	−·0313	+·0065	−·0009	+·0093	−·0188
B_2	−·0104	+·0105	−·0338	+·0033	+·0101	−·0008
A_3	+·0009	+·0087	−·0074	−·0025	−·0001	−·0063
B_3	−·0004	−·0074	+·0152	−·0015	+·0044	+·0032
A_4	−·0005	+·0043	+·0067	−·0001	+·0015	−·0046
B_4	−·0013	+·0026	−·0041	−·0013	+·0016	−·0003
A_5	+·0105	−·0101	+·0037	+·0009	−·0052	+·0024
B_5	−·0184	+·0075	+·0020	−·0014	+·0088	−·0109
A_6	−·0198	+·0012	−·0011	−·0007	−·0004	−·0097
B_6	−·0042	+·0009	+·0017	+·0017	−·0020	−·0067
A_7	−·0030	+·0039	−·0145	−·0002	+·0021	+·0086
B_7	−·0035	+·0042	+·0014	−·0010	−·0031	−·0103
A_8	+·0002	−·0009	−·0431	+·0005	+·0008	+·0029
B_8	+·0001	+·0064	+·0362	−·0014	−·0010	−·0030

Values of A_1, B_1, A_2, &c., to second Approximation.

	S	K	L	M	N	O
	$(\gamma-\eta)$	(γ)	$(\gamma-\frac{1}{2}\sigma-\frac{1}{2}\varpi)$	$(\gamma-\sigma)$	$(\gamma-\frac{3}{2}\sigma+\frac{1}{2}\varpi)$	$(\gamma-2\sigma)$
A_1	+0·0256	−0·2050	−0·0284	+0·0136	+0·0332	−0·2931
B_1	−0·0270	−0·0237	−0·0070	−0·0055	+0·0016	+0·0631
A_2	+1·5616	−0·4227	−0·2341	−4·3167	+0·8098	−0·0716
B_2	+1·0027	−0·0166	+0·3007	+4·5004	−0·7443	+0·0001
A_3	+0·0077	−0·0050	−0·0022	−0·0113	−0·0007	−0·0010
B_3	+0·0008	+0·0089	−0·0059	+0·0423	+0·0067	+0·0046
A_4	+0·0300	−0·0170	−0·0524	−0·5442	−0·0109	+0·0076
B_4	+0·0022	−0·0047	−0·0886	−0·0865	−0·0138	+0·0037
A_5	−0·0105	+0·0050	−0·0060	+0·0023	+0·0039	−0·0002
B_5	+0·0213	−0·0003	+0·0026	+0·0033	−0·0036	+0·0035
A_6	+0·0215	−0·0020	−0·0039	−0·1125	−0·0283	+0·0035
B_6	+0·0110	+0·0018	−0·0096	−0·1131	−0·0004	+0·0107
A_7	+0·0038	−0·0009	+0·0089	+0·0023	−0·0043	+0·0116
B_7	+0·0081	−0·0053	+0·0029	−0·0021	+0·0027	+0·0019
A_8	+0·0009	+0·0067	+0·0010	+0·0290	+0·0040	−0·0086
B_8	+0·0027	−0·0097	−0·0050	−0·0402	+0·0009	+0·0103
A_0	10·1988	10·1989	10·1843	10·1992	10·1853	10·1971

23. The values A_2, B_2 in columns S and M express the mean solar semidiurnal and mean lunar semidiurnal tides.

A_2, B_2 of column K express the luni-solar declinational semidiurnal tide.

A_2, B_2 of columns L and N express two constituents of the lunar elliptic semidiurnal tide.

A_2, B_2 of column O express zero tolerably well*.

A_1, B_1 of columns K and O express the two constituents of the lunar diurnal tide.

A_1, B_1 of column S express one constituent of the solar elliptic diurnal tide.

A_1, B_1 of column M express one constituent of the lunar elliptic diurnal tide†.

A_1, B_1 of columns L and N possibly depend on the elliptic lunar diurnal tides, but will no doubt be found a better approximation to zero when calculated by the average of several years. There is no tide corresponding strictly to them.

A_3, B_3 are, as they ought to be, very good approximations to zero in all the columns except M. Their values in this column constitute, probably, a genuine expression of the terdiurnal lunar tide [not included in the preceding general schedule (§ 3) but referred to in § 4], investigated by Laplace as depending on the fourth power of the moon's parallax.

A_4, B_4 express shallow-water tides‡ derived from the *lunar* semidiurnal tide, according to precisely the same dynamical principle as that by which Helmholtz has explained the overtones generated in very loud sounds, even when the source of the sound is a simple harmonic motion. There ought to be no sensible tide expressed by A_4 and B_4 in column L; and the comparative largeness of these numbers is probably an accident, owing either to errors of observation or the imperfection of the system of combination adopted, or a chance concurrence of disturbance due to wind &c.

A_5, B_5 in almost every column approximate remarkably well to zero; and even their greatest values (those of column S) express merely a deviation of $\frac{1}{40}$ of a foot (or 0·3 of an inch) on each side of the mean level.

A_6, B_6 may be considered as insensible for every column except M, for which they express, as they ought to do, an undoubtedly genuine shallow-water tide, being the second harmonic (as it were overtone) of the lunar semidiurnal tide.

A_7, B_7 are very good approximations to zero in all the columns.

A_8, B_8 in column M express probably a genuine, though very small, shallow-water tide, the third harmonic of the lunar semidiurnal tide. There is a very good approximation to zero in all of the other columns.

It is interesting, with reference to the mode of reduction which has been adopted, to remark to how nearly zero the comparatively large values of A_7, B_7 in column O and A_8, B_8 in column L of the first approximation are reduced by the corrections found in the second approximation explained above.

24. Selecting from the preceding Table the coefficients, which are each probably a genuine tide, and applying the proper corrections (Everett, Roy. Soc. Edin. Trans. 1860), which are the following:—

* There being no theoretical tide of the period corresponding to them.

† Being the resultant of the two whose speeds are $\gamma-\sigma+\varpi$ and $\gamma-\sigma-\varpi$, inasmuch as for a single year the effect of the $\pm\varpi$ may be neglected.

‡ It is this term that makes the whole resultant tide rise faster than it falls, as is generally observed in estuaries and other localities separated from the oceans by considerable spaces of shallow water.

	Augmenting factor.
A_1, B_1	·0028
A_2, B_2	·0115
A_3, B_3	·0262
A_4, B_4	·0472
A_6, B_6	·1107
A_8, B_8	·2092

to take account of the circumstance that the mean height for each hour has been taken virtually for the height at the middle of the hour, we find corrected values for the coefficients (A, B), from which we have the following amplitudes and epochs, according to notation of § 3:—

Ramsgate, 1864.

	S	K	L	M	N	O
	$(\gamma-\eta)$	(γ)	$(\gamma-\frac{1}{2}\sigma-\frac{1}{2}\varpi)$	$(\gamma-\sigma)$	$(\gamma-\frac{3}{2}\sigma+\frac{1}{2}\varpi)$	$(\gamma-2\sigma)$
R_1	0·0373	0·2070	......	0·0145	......	0·3008
ϵ_1	313°·48	186°·60	......	337°·98	......	167°·85
R_2	1·8772	0·4279	0·3856	6·3078	1·1126	......
ϵ_2	32°·70	182°·25	127°·90	133°·81	317°·41	......
R_3	......	......	......	0·0448	......	......
ϵ_3	......	......	......	104°·96	......	......
R_4	0·0315	......	......	0·5771	......	......
ϵ_4	4°·19	......	......	189°·03	......	......
R_6	0·0268	......	......	0·1771	......	......
ϵ_6	27°·04	......	......	225°·14	......	......
R_8	......	......	......	0·0599	......	......
ϵ_8	......	......	......	305°·86	......	......

25. The hour-angles of the ideal stars having been assumed to be each equal to zero at the commencement of the observations, the previously found epochs (ϵ_1, ϵ_2, &c.) have to be corrected for this assumption in order that the tide-components may be referred to the *true* positions of the ideal stars. The correction to be added to the epoch of the diurnal tides will be equal to the *true* hour-angle of the ideal star at the commencement of the observations. In the semidiurnal the correction will be equal to twice the hour-angle, for the terdiurnal three times, and so on. The longitudes of the sun and moon and of the lunar perigee used in getting the true hour-angles will necessarily be their mean longitudes. In addition to the above six series, others have since been analyzed and included in the schedule. The amplitudes and the corrected epochs of the whole are as follow:—

Yr. 1864. $A_0 = 10·1988$ ft. Average inclination of moon's orbit to earth's equator (I) = 20°·3.

	S	M	L	N	MS	2SM	3MS
	$(\gamma-\eta)$	$(\gamma-\sigma)$	$(\gamma-\frac{1}{2}\sigma-\frac{1}{2}\varpi)$	$(\gamma-\frac{3}{2}\sigma+\frac{1}{2}\varpi)$	$(\gamma-\frac{1}{2}\sigma-\frac{1}{2}\eta)$	$(\gamma+\sigma-2\eta)$	$(\gamma-\frac{3}{2}\sigma+\frac{1}{2}\eta)$
R_1	0·0373	......	......	......	......	......	......
ϵ_1	313°·48	......	......	......	......	......	......
R_2	1·8772	6·3078	0·3856	1·1126	......	0·1445	......
ϵ_2	32°·70	339°·43	186°·28	310°·31	......	263°·02	......
R_3	......	0·0448	......	......	......	......	......
ϵ_3	......	53°·39	......	......	......	......	......
R_4	0·0315	0·5771	......	......	0·3332	......	0·0276
ϵ_4	4°·19	240°·27	......	......	125°·35	......	335°·03
R_6	0·0268	0·1771	......	......	......	......	......
ϵ_6	27°·04	122°·00	......	......	......	......	......
R_8	......	0·0599	......	......	......	......	......
ϵ_8	......	48°·34	......	......	......	......	......

	K	O	P	λ	ν	μ or 2MS
	(γ)	$(\gamma-2\sigma)$	$(\gamma-2\eta)$	$(\gamma-\frac{1}{2}\sigma+\frac{1}{2}\varpi-\eta)$	$(\gamma-\frac{3}{2}\sigma-\frac{1}{2}\varpi+\eta)$	$(\gamma-2\sigma+\eta)$
R_1	0·2070	0·3008	0·0730	......	......	......
ϵ_1	100°·75	99°·34	262°·58	......	......	......
R_2	0·4279	......	......	0·1785	0·3526	0·2639
ϵ_2	10°·55	......	......	169°·97	328°·05	83°·79

26. In the determination of the long-period tides the mean height of the tide for each solar day, *i. e.* the mean of the twenty-four hourly heights as originally taken from the diagram-sheets, must be taken. This will give 365 means in an ordinary year; in leap year the last mean must be disregarded, the subsequent equations being adapted for only 365 means. It will be necessary to clear the means thus obtained of all undue lunar influence, inasmuch as the periods of the lunar tides are not commensurable with the solar twenty-four hours. In practice the tide-components evaluated from the series named, for brevity, M, N, and O are generally found to be the only ones which have any sensible effect. The necessary correction to be applied to these means, on account of the semidiurnal tides of M and N, is

$$\frac{R_2}{24}\times\frac{\sin 12n}{\sin\frac{1}{2}n}\times\cos(2nt-\epsilon_2),$$

and for the diurnal tide of O

$$\frac{R_1}{24}\times\frac{\sin 12n}{\sin\frac{1}{2}n}\times\cos(nt-\epsilon_1),$$

where nt is the hour-angle of the ideal star at the time corresponding to the mean of the times for which the heights have been given. If the observations of the tide-heights have been commenced at noon, then the mean of the times for the first day will correspond to $11\frac{1}{2}$ hours of that day. The values of $(nt-\epsilon)$ for each ideal star (M, N, and O) having been found for $11\frac{1}{2}$ hours of the first day, then the values for succeeding days will be found from those of the first day by addition of the respective daily variations of nt. The first part of the formula will form a constant for each tide, and the corrections are found by multiplying these constants into the cosines of the respective values of $(nt-\epsilon)$. The mean height, minus the sum of these corrections, will give the purified mean for each day. The next step is to take the mean of the 365 purified daily means, and to subtract the purified daily mean of each day from the mean height thus found. This will give 365 small differences (termed hereafter δh), and it is on these differences that the calculation for the long-period tides is based.

27. The value of δh for each day is assumed equal to the following formula:—

$$\begin{aligned}\delta h = \;& A\cos(\sigma-\varpi)t + B\sin(\sigma-\varpi)t\\ &+C\cos 2\sigma t \quad + D\sin 2\sigma t\\ &+C'\cos 2(\sigma-\eta)t + D'\sin 2(\sigma-\eta)t\\ &+E\cos\eta t \quad + F\sin\eta t\\ &+G\cos 2\eta t \quad + H\sin 2\eta t,\end{aligned}$$

in which

A and B express the coefficients of the lunar monthly elliptic tide,
C „ D „ „ lunar fortnightly declinational tide,
C′ „ D′ „ „ lunisolar synodic fortnightly tide,
E „ F „ „ solar annual elliptic tide,
G „ H „ „ solar semiannual declinational tide.

The equations are solved by the method of least squares—that is, the values of δh are multiplied by the respective values of $\cos(\sigma-\varpi)t$, $\sin(\sigma-\varpi)t$, $\cos 2\sigma t$, $\sin 2\sigma t$, &c., and the products added together. The left-hand components of ten equations are thus formed. The right-hand components will be constant for each year—that is, on the assumption that the value of nt is $0^{\circ}{\cdot}0$ at the commencement of the year. The following formulæ have been calculated, giving the values of the coefficients for the right-hand components of the equations on the above assumption:—

$$
\begin{array}{lllllllllll}
\Sigma_0^{364}\delta h\,.\cos(\sigma-\varpi)t & =+183{\cdot}05\,A+ & 2{\cdot}14\,B+ & 0{\cdot}73\,C+ & 4{\cdot}29\,D+ & 0{\cdot}77\,C'+ & 5{\cdot}04\,D'+ & 4{\cdot}88\,E- & 0{\cdot}34\,F+ & 4{\cdot}96\,G- & 0{\cdot}69\,H. \\
\Sigma_0^{364}\delta h\,.\sin(\sigma-\varpi)t & =+\quad 2{\cdot}14\,A+ & 181{\cdot}95\,B- & 4{\cdot}15\,C+ & 1{\cdot}02\,D- & 4{\cdot}90\,C'+ & 1{\cdot}07\,D'+ & 3{\cdot}80\,E+ & 0{\cdot}34\,F+ & 3{\cdot}88\,G+ & 0{\cdot}69\,H. \\
\Sigma_0^{364}\delta h\,.\cos 2\sigma t & =+\quad 0{\cdot}73\,A- & 4{\cdot}15\,B+ & 183{\cdot}18\,C+ & 0{\cdot}88\,D+ & 0{\cdot}61\,C'+ & 0{\cdot}92\,D'- & 1{\cdot}50\,E- & 0{\cdot}10\,F- & 1{\cdot}51\,G- & 0{\cdot}19\,H. \\
\Sigma_0^{364}\delta h\,.\sin 2\sigma t & =+\quad 4{\cdot}29\,A+ & 1{\cdot}02\,B+ & 0{\cdot}88\,C+ & 181{\cdot}82\,D+ & 0{\cdot}92\,C'- & 0{\cdot}75\,D'+ & 3{\cdot}05\,E- & 0{\cdot}08\,F+ & 3{\cdot}06\,G- & 0{\cdot}17\,H. \\
\Sigma_0^{364}\delta h\,.\cos 2(\sigma-\eta)t & =+\quad 0{\cdot}77\,A- & 4{\cdot}90\,B+ & 0{\cdot}61\,C+ & 0{\cdot}92\,D+ & 183{\cdot}19\,C'+ & 0{\cdot}97\,D'- & 1{\cdot}68\,E- & 0{\cdot}11\,F- & 1{\cdot}70\,G- & 0{\cdot}23\,H. \\
\Sigma_0^{364}\delta h\,.\sin 2(\sigma-\eta)t & =+\quad 5{\cdot}04\,A+ & 1{\cdot}07\,B+ & 0{\cdot}92\,C- & 0{\cdot}75\,D+ & 0{\cdot}97\,C'+ & 181{\cdot}81\,D'+ & 3{\cdot}25\,E- & 0{\cdot}10\,F+ & 3{\cdot}27\,G- & 0{\cdot}23\,H. \\
\Sigma_0^{331}\delta h\,.\cos \eta t & =+\quad 4{\cdot}88\,A+ & 3{\cdot}80\,B- & 1{\cdot}50\,C+ & 3{\cdot}05\,D- & 1{\cdot}68\,C'+ & 3{\cdot}25\,D'+ & 182{\cdot}43\,E+ & 0{\cdot}00\,F- & 0{\cdot}14\,G+ & 0{\cdot}00\,H. \\
\Sigma_0^{364}\delta h\,.\sin \eta t & =-\quad 0{\cdot}34\,A+ & 0{\cdot}34\,B- & 0{\cdot}10\,C- & 0{\cdot}08\,D- & 0{\cdot}11\,C'- & 0{\cdot}10\,D'+ & 0{\cdot}00\,E+ & 182{\cdot}57\,F+ & 0{\cdot}00\,G+ & 0{\cdot}00\,H. \\
\Sigma_0^{364}\delta h\,.\cos 2\eta t & =+\quad 4{\cdot}96\,A+ & 3{\cdot}88\,B- & 1{\cdot}51\,C+ & 3{\cdot}06\,D- & 1{\cdot}70\,C'+ & 3{\cdot}27\,D'- & 0{\cdot}14\,E+ & 0{\cdot}00\,F+ & 182{\cdot}43\,G+ & 0{\cdot}00\,H. \\
\Sigma_0^{364}\delta h\,.\sin 2\eta t & =-\quad 0{\cdot}69\,A+ & 0{\cdot}69\,B- & 0{\cdot}19\,C- & 0{\cdot}17\,D- & 0{\cdot}23\,C'- & 0{\cdot}23\,D'+ & 0{\cdot}00\,E+ & 0{\cdot}00\,F+ & 0{\cdot}00\,G+ & 182{\cdot}57\,H.
\end{array}
$$

28. These equations, solved by successive approximations, give the following values of the coefficients for Ramsgate, 1864:—

ft.

$\left.\begin{array}{l} A = +0{\cdot}0109 \\ B = +0{\cdot}0296 \end{array}\right\}$ the coefficients for the lunar monthly tide (elliptic).

$R = 0{\cdot}0316 \quad \epsilon = 69^\circ{\cdot}78.$

$\left.\begin{array}{l} C = +0{\cdot}0181 \\ D = +0{\cdot}0277 \end{array}\right\}$ the coefficients for the lunar fortnightly tide (declinational).

$R = 0{\cdot}0331 \quad \epsilon = 56^\circ{\cdot}83.$

$\left.\begin{array}{l} C' = -0{\cdot}0815 \\ D' = -0{\cdot}0508 \end{array}\right\}$ the coefficients for the lunisolar fortnightly shallow-water tide (synodic).

$R = 0{\cdot}0960 \quad \epsilon = 211^\circ{\cdot}93.$

$\left.\begin{array}{l} E = -0{\cdot}0367 \\ F = -0{\cdot}1216 \end{array}\right\}$ the coefficients for the solar annual tide (elliptic and meteorological).

$R = 0{\cdot}1270 \quad \epsilon = 253^\circ{\cdot}20.$

$\left.\begin{array}{l} G = +0{\cdot}0225 \\ H = +0{\cdot}0713 \end{array}\right\}$ the coefficients for the solar semiannual tide (declinational and meteorological?).

$R = 0{\cdot}0748 \quad \epsilon = 72^\circ{\cdot}48.$

29. The epochs of these long-period tides have also to be corrected on account of their phases having been each assumed equal to zero at the commencement of the observations, or, more strictly, at the time corresponding to the mean of the first twenty-four hourly observations. The amplitudes require no augmentation. The amplitudes and corrected epochs are as follow:—

Long-period Tides.

Speed	$(\sigma-\varpi)$	2σ	$2(\sigma-\eta)$	η	2η
	ft.	ft.	ft.	ft.	ft.
R	0·0316	0·0331	0·0960	0·1270	0·0748
ϵ	45°·09	268°·29	207°·85	180°·97	288°·02

The reduction of the Ramsgate observations, so far as at present discussed, consists in the analysis of the year 1864 only.

30. A series of tide-records, taken near the entrance of the George's Docks, Liverpool, has been supplied, on application, by the kindness of the Board of the Mersey Dock Estate. The heights through about twelve hours each, during a few interruptions in the tide-curve (caused by the accidental stopping of the clock &c.), have been inferred from the tide-diagrams of the self-registering tide-gauge at Helbre Island, at the mouth of the Dee.

The following years have been selected and analyzed in a manner quite similar to that previously described for Ramsgate. It should have been stated that the epochs of the tide-components for Ramsgate, Liverpool, and also for Portland Breakwater, hereafter described, have been referred to the meridian of Greenwich, Greenwich mean time having been used in the records of the observations.

31. Liverpool (Lat. 53° 40′ N., Long. 0^h 20^m W. of Greenwich).

Year ...	1857-58.	1858-59.	1859-60.	1866-67.	1867-68.	1868-69.	1869-70.
	ft.	ft.	ft.	ft.	ft.	ft.	ft.
$A_0 =$	16·7192	16·8208	16·8289	16·8998	17·0862	17·4877	17·1350
I* =	28°·5	27°·9	27°·0	18°·4	18°·4	19°·3	20°·6

* I is the average inclination of the Moon's orbit to the Earth's equator, or the mean *maximum* declination, for the period.

S. Speed of semidiurnal $2(\gamma-\eta)$.

	1857–58.	1858–59.	1859–60.	1866–67.	1867–68.	1868–69.	1869–70.
R_1	0·0453	0·0696	0·0844	0·0470	0·0349	0·0399	0·0276
ϵ_1	69°·93	59°·78	56°·55	39°·04	66°·18	101°·28	124°·38
R_2	3·2149	3·3124	3·1938	3·1304	3·0990	3·1217	3·0516
ϵ_2	11°·78	11°·12	10°·08	11°·63	11°·31	11°·88	13°·63
R_4	0·0612	0·0600	0·0476	0·0475	0·0678	0·0640	0·0508
ϵ_4	322°·23	330°·18	294°·73	314°·32	327°·11	298°·49	312°·61

M. Speed of semidiurnal $2(\gamma-\sigma)$.

	1857–58.	1858–59.	1859–60.	1866–67.	1867–68.	1868–69.	1869–70.
R_1	0·0192	0·0626	0·0092	0·0396	0·0194	0·0603	0·0841
ϵ_1	332°·19	266°·69	77°·27	358°·02	259°·28	322°·82	317°·18
R_2	9·6745	9·8124	9·8930	10·2713	10·2648	10·1210	10·1443
ϵ_2	326°·10	325°·45	323°·99	325°·55	326°·85	328°·38	329°·40
R_3	0·1053	0·0984	0·1525	0·0862	0·1022	0·1158	0·1014
ϵ_3	330°·60	315°·04	321°·71	335°·27	327°·43	324°·76	313°·23
R_4	0·6847	0·6573	0·6371	0·7648	0·7238	0·7018	0·7196
ϵ_4	220°·34	217° 68	221° 30	224°·19	222°·50	223°·68	227°·87
R_6	0·1812	0·1887	0·2093	0·2057	0·1936	0·1888	0·2200
ϵ_6	342°·76	348°·21	343°·17	343° 80	348° 52	353°·91	3°·47
R_8	0·0582	0·0808	0·0658	0·0667	0·0670	0·0665	0·0770
ϵ_8	262°·38	278°·17	259°·39	282°·09	280°·89	295°·60	293°·50

MS. Speed $(4\gamma-2\sigma-2\eta)$.

	1857–58.	1858–59.	1859–60.	1866–67.	1867–68.	1868–69.	1869–70.
R_4	0·4379	0·3488	0·3879	0·4635	0·4153	0·4080	0·3957
ϵ_4	270°·68	265°·86	270°·49	269°·45	271°·86	269°·15	272° 96

2SM. Speed $2(\gamma+\sigma-2\eta)$.

	1857–58.	1858–59.	1859–60.	1866–67.	1867–68.	1868–69.	1869–70.
R_2	0·1346	0·1595	0·1466	0·1390	0·1163	0·1402	0·1206
ϵ_2	206°·12	216°·66	229°·57	222°·06	224°·05	224°·11	233°·51

3MS. Speed $(4\gamma-6\sigma+2\eta)$.

	1857–58.	1858–59.	1859–60.	1866–67.	1867–68.	1868–69.	1869–70.
R_4	0·0063	0·0212	0·0185	0·0210	0·0313	0·0495	0·0140
ϵ_4	193°·37	52°·16	29°·94	26°·90	58°·11	43°·78	45°·20

K. Speed of semidiurnal (2γ).

	1857–58.	1858–59.	1859–60.	1866–67.	1867–68.	1868–69.	1869–70.
R_1	0·3930	0·3978	0·3853	0·3278	0·2939	0·3116	0·3404
ϵ_1	283°·95	283°·08	273° 18	281°·60	289°·15	289°·46	293° 88
R_2	1·1850	1·2742	1·0995	0·6336	0·7701	0·7346	0·7882
ϵ_2	5°·98	0° 40	349°·61	9°·03	13°·39	12°·66	21°·75

O. Speed $(\gamma-2\sigma)$.

	1857–58.	1858–59.	1859–60.	1866–67.	1867–68.	1868–69.	1869–70.
R_1	0·4410	0·4136	0·4519	0·3058	0·2694	0·3374	0·3214
ϵ_1	316°·69	316°·28	318°·81	312°·74	308°·13	301°·88	296°·29

P. Speed $(\gamma-2\eta)$.

	1857-58.	1858-59.	1859-60.	1866-67.	1867-68.	1868-69.	1869-70.
R_1	0·1250	0·1339	0·1306	0·1409	0·1357	0·1333	0·0935
ϵ_1	101°·96	105°·75	98°·61	88°·43	109°·17	84°·21	77°·08

L. Speed $(2\gamma-\sigma-\varpi)$.

	1857-58.	1858-59.	1859-60.	1866-67.	1867-68.	1868-69.	1869-70.
R_2	0·5069	0·7849	0·3459	0·6015	0·5842	0·5129	0·4671
ϵ_2	157°·93	168°·91	144°·51	124°·08	151°·51	159°·39	151°·91

N. Speed $(2\gamma-3\sigma+\varpi)$.

	1857-58.	1858-59.	1859-60.	1866-67.	1867-68.	1868-69.	1869-70.
R_2	1·8608	1·7607	1·9716	2·1608	1·9124	1·8307	1·8917
ϵ_2	303°·52	308°·72	303°·98	301°·59	308°·14	307°·39	305°·06

R. Speed $(2\gamma-\eta)$. T. Speed $(2\gamma-3\eta)$.

	R. 1857-58 & 1858-59.	R. 1858-59 & 1859-60.	T. 1857-58 & 1858-59.	T. 1858-59 & 1859-60.
R_2	0·1006	0·0818	0·3490	0·1208
ϵ_2	146°·45	146°·60	67°·97	36°·78

λ. Speed $(2\gamma-\sigma+\varpi-2\eta)$.

	1857-58.	1858-59.	1859-60.	1866-67.	1867-68.	1868-69.	1869-70.
R_2	0·4091	0·2262	0·1165	0·2369	0·2166	0·1977	0·1913
ϵ_2	141°·68	134°·46	191°·08	175°·95	180°·68	138°·54	132°·16

ν. Speed $(2\gamma-3\sigma-\varpi+2\eta)$.

	1857-58.	1858-59.	1859-60.	1866-67.	1867-68.	1868-69.	1869-70.
R	0·7423	0·6303	0·2841	0·7182	0·5051	0·1423	0·6912
ϵ_2	307°·91	284°·01	261°·09	278°·43	267°·42	311°·51	332°·41

μ, or 2MS. Speed $2(\gamma-2\sigma+\eta)$.

	1857-58.	1858-59.	1859-60.	1866-67.	1867-68.	1868-69.	1869-70.
R_2	0·2860	0·2259	0·3076	0·2561	0·2278	0·2576	0·2303
ϵ_2	31°·72	42°·04	32°·55	32°·42	31°·94	64°·20	39°·64

32. The analysis of the long-period tides of Liverpool has at present been limited to the first four of the seven selected years. The results are as follows:—

Speed		$(\sigma-\varpi)$	2σ	$2(\sigma-\eta)$	η	2η
1857-58.	R	0·046	0·093	0·068	0·359	0·090
	ε	289°·4	170°·7	111° 8	209°·6	144°·1
1858-59.	R	0·198	0·037	0·020	0·284	0·104
	ε	31° 6	148°·8	325°·5	258°·7	269° 6
1859-60.	R	0·152	0·024	0·079	0·353	0·190
	ε	172°·8	72°·9	303°·4	213°·4	112°·3
1866-67.	R	0·072	0·036	0·053	0·452	0·185
	ε	259°·8	340°·6	67°·9	272°·3	228°·7

33. The agreements between the analyzed amplitudes and epochs for the whole of the short-period tides are, on the whole, satisfactory. The chief discordances occur between the evaluated quantities of the lunar elliptic semidiurnal tides L, N, λ, and ν. It is extremely probable that a period extending through two entire years would give a much better agreement between these quantities, the period being more nearly commensurable with the majority of the chief tides, the period at present selected eliminating only that of the mean lunar semidiurnal (M) tide. The values of the mean sea-level show a general increase, although the value deduced for 1868–69 stands out prominently from those deduced for the preceding and following years. This uncertainty will affect sometimes, to a considerable amount, the prediction of tide-heights from a *fixed datum*, although such results are better and more intelligible than predictions reckoned from low water of ordinary spring-tides.

34. Through the kindness of Prof. J. E. Hilgard, of the United States Coast Survey Office, three years' tidal observations, taken at Fort Point (lat. 37°·67 N., long. 8^h·15 W. of Greenwich), San Francisco Bay, California, were received and analyzed, with the following results:—

Year ...	1858–59.	1859–60.	1860–61.
	ft.	ft.	ft.
$A_0=$	8·7103	8·2651	8·1608
I =	28°·0	26° 9	25°·4

	S. Speed of semidiurnal $2(\gamma-\eta)$.			M. Speed of semidiurnal $2(\gamma-\sigma)$.		
	1858-59.	1859–60.	1860–61.	1858–59.	1859–60.	1860–61.
R_1	0·0146	very small.	very small.	0·0539	0·0808	0·0863
ϵ_1	211°·96	......	......	46°·30	189°·37	32°·71
R_2	0·4067	0·3802	0·3824	1·6694	1·6215	1·6645
ϵ_2	334°·24	335°·80	336°·45	330°·81	331°·30	328°·72
R_3	......	......	......	very small.	very small.	very small.
ϵ_3	......	......	......	......	......	......
R_4	very small.	very small.	very small.	0·0616	0·0712	0·0698
ϵ_4	......	......	......	23°·32	26°·73	11°·15

MS. Speed $(4\gamma-2\sigma-2\eta)$.

	1858–59.	1859–60.	1860–61.
R_4	0·0248	0·0325	0·0315
ϵ_4	22°·33	12°·25	22°·81

K. Speed of semidiurnal (2γ).

	1858–59.	1859–60.	1860–61.
R_1	1·3370	1·3036	1·2925
ϵ_1	192°·17	190°·88	188°·55
R_2	0·1759	0·1716	0·1351
ϵ_2	326°·65	314°·53	308°·75

	O. Speed $(\gamma-2\sigma)$.			P. Speed $(\gamma-2\eta)$.		
	1858–59.	1859–60.	1860–61.	1858–59.	1859–60.	1860–61.
R_1	0·8917	0·8511	0·8784	0·3672	0·3659	0·3869
ϵ_1	3°·39	6°·25	4°·01	16°·52	15°·90	13°·52

L. Speed $(2\gamma-\sigma-\varpi)$.

	1858–59.	1859–60.	1860–61.
R_2	0·0591	0·0370	0·0506
ϵ_2	102°·63	183°·00	170°·16

N. Speed $(2\gamma-3\sigma+\varpi)$.

	1858–59.	1859–60.	1860–61.
R_2	0·3931	0·3494	0·3545
ϵ_2	303°·46	305°·53	302°·51

R. Speed $(2\gamma-\eta)$.

	1858–59 and 1859–60.
R_2	0·0076
ϵ_2	164°·00

T. Speed $(2\gamma-3\eta)$.

	1858–59 and 1859–60.
R_2	0·0142
ϵ_2	277°·90

λ. Speed $(2\gamma-\sigma+\varpi-2\eta)$.

	1858–59.	1859–60.	1860–61.
R_2	0·0372	0·0275	0·0121
ϵ_2	183°·30	156°·39	144°·18

ν. Speed $(2\gamma-3\sigma-\varpi+2\eta)$.

	1858–59.	1859–60.	1860–61.
R_2	0·1044	0·0387	0·0437
ϵ_2	287°·23	272°·46	349°·59

μ or 2MS. Speed $2(\gamma-2\sigma+\eta)$.

	1858–59.	1859–60.	1860–61.
R_2	0·0257	0·0311	0·0252
ϵ_2	254°·34	206°·14	209°·53

J. Speed $(\gamma+\sigma-\varpi)$.

	1858–59.	1859–60.	1860–61.
R_1	0·0819	0·0376	0·0565
ϵ_1	213°·98	208°·29	183°·40

Q. Speed $(\gamma-3\sigma+\varpi)$.

	1858–59.	1859–60.	1860–61.
R_1	0·1706	0·1056	0·1332
ϵ_1	353°·03	331°·34	8°·93

35. Here, again, we have an abrupt diminution in the height of mean level for the first two years, which the following extract from a letter received from Prof. J. E. Hilgard, fully explains:—

"The change in the mean-level reading at Fort Point is a matter of much "annoyance to us. The tide-gauge was put up in a small building near the "end of a wharf, and the tide-staff used for comparison was close to it. Now "it was observed after the observations had continued some time that the "wharf was settling,—at least the part where the gauge stood. Then the "gauge was moved to a point a little nearer to the shore believed to be firm, "but we think the whole wharf settled and continued to do so for years. "There seems to be a bog formation underlying the surface deposit at that "place. There is probably no way of ascertaining the amount of settling "except from the observations themselves. We are now having frequent "levellings made, referring the tide-staff to a rocky ledge further inland."

36. It having come to the knowledge of the Tide Committee that the United States Coast Survey Office was in possession of a series of hourly tide observations taken at Cat Island in the Gulf of Mexico, and which were of a very remarkable and interesting character, it was thought a favourable opportunity of testing the value of the harmonic analysis for the evaluation of the components of the tides of this place, which appeared very complicated and peculiar. Application having been made, a series of about thirteen months were received through the kindness of Prof. J. E. Hilgard.

The following results represent the tide-components as far as they have at present been evaluated. *Datum* 10 feet *below* datum of United States Coast Survey:—

Cat Island, Gulf of Mexico (Lat. 30°·23 N., Long. 5^h·94 W. of Greenwich).

Year 1848. $A_0=4·8574$ ft. $I=18°·45$.

	S	M	L	N
Speed	$(\gamma-\eta)$	$(\gamma-\sigma)$	$(\gamma-\frac{1}{2}\sigma-\frac{1}{2}\varpi)$	$(\gamma-\frac{3}{2}\sigma+\frac{1}{2}\varpi)$
R_1	0·0442	0·0101	......	......
ϵ_1	10°·04	95°·21	......	......
R_2	0·0677	0·1195	0·0118	0·0269
ϵ_2	23°·80	10°·75	222°·40	33°·57

	K	O	P	J	Q
Speed	(γ)	$(\gamma-2\sigma)$	$(\gamma-2\eta)$	$(\gamma+\sigma-\varpi)$	$(\gamma-3\sigma+\varpi)$
R_1	0·4627	0·3855	0·1559	0·0292	0·0733
ϵ_1	55°·20	224°·29	230°·65	28°·22	215°·32
R_2	0·0205	......	......	......	......
ϵ_2	288°·73	......	......	......	......

37. It is extremely intresting to find that, although the lunar and solar semidiurnal tides are very small in value, the series of means from which they were obtained being extremely regular and good, the consequent determination of the phase of spring-tides (§ 50) from their respective epochs is probably correct within a few minutes. The proportion between the amplitudes of the lunar and solar semidiurnal tides is the nearest approach to equality yet obtained, being in the ratio of 11 to 6. The comparatively large value of R_1 of Series S is undoubtedly a genuine tide, but the smallness of the corresponding value of Series M must forbid the conclusion of its being purely astronomical. It is perhaps produced by temperature or wind, its time of maximum being about 40 minutes after noon. There are also indications of a similar and large annual tide of 0·274 foot amplitude, and maximum about Aug. 16, which is also probably meteorological in its origin. The proportion between the lunar and solar diurnal (Declinational) tides (R_1 of Series O and P) will be, on the assumption of the variation of R_1 of Series O being as the square of the sine of the declination, about 4 to 1.

38. The following are the values of the long-period tides:—

	R ft.	ε °
Solar annual tide (elliptic and meteorological)	0·274	144·50
Solar semiannual tide (declinational and meteorological) ...	0·128	35·02
Lunar monthly tide (elliptic)	0·106	304·17
Lunar fortnightly tide (declinational)	0·043	136·69
Lunisolar fortnightly tide (synodic)............................	0·099	336·26

39. Professor Fuller having applied to Mr. Parkes for a set of tide-observations of any port in India, that gentleman kindly placed at the disposal of the Committee, for analysis, a series of personal tide observations taken at Bombay from January 29, 1867 to June 4, 1867. The heights were observed at successive intervals of ten minutes, and were taken under the superintendence of Mr. Ormiston, C.E. A few breaks of short duration in the observations have been supplied from a curve plotted for each day of interrupted observation. The datum-line is 72 feet below the level of the Town-Hall datum.

40. The observations were not used as they were given, but heights for each quarter hour, the heights for the fifteen and forty-five minutes past each hour being interpolated. Tables similar to those previously described (§ 16), but adapted for the reduction of observations taken for every quarter hour, have been made for a period of 127 days.

The following are the results of those tides for which so short a period (127 days) is likely to give fair results :—

Bombay (Lat. 18°·95 N., Long. 4^h·86 E. of Greenwich).

Year 1867. I=18°.34. A_0=8·2004 ft.

	S	M	L	N	K	O
Speed ...	$(\gamma-\eta)$	$(\gamma-\sigma)$	$(\gamma-\frac{1}{2}\sigma-\frac{1}{2}\varpi)$	$(\gamma-\frac{3}{2}\sigma+\frac{1}{2}\varpi)$	(γ)	$(\gamma-2\sigma)$
R_1	......	0·1061	......	......	1·1620	0·5577
ϵ_1	......	210°·94	......	......	193°·31	10°·50
R_2	1·8514	4·3680	0·3189	0·9833	0·8835	......
ϵ_2	85°·38	59°·30	184°·41	35°·18	188°·62	......
R_3	......	0·0838	......	......	......	......
ϵ_3	......	75°·45	......	......	......	......
R_4	0·0232	0·1060	......	......	......	......
ϵ_4	165°·40	16° 82	......	......	......	.. ...

41. A series of tide-observations extending through three years, commencing 1868, May 1, taken by the Manora self-registering tide-gauge at Kurrachee, were also kindly lent by Mr. Parkes for the purpose of reduction. The following series have been analyzed for each year separately, with the exception of the solar semidiurnal tide-components R and T, for which it is necessary to combine the observations extending through two entire years. The datum-line is 2 feet *below* the datum-line of the diagram-sheets.

42. Kurrachee (Lat. 24°·9 N., Long. 4^h·47 E. of Greenwich).

S. Speed of semidiurnal $2(\gamma-\eta)$.

	1868-69.	1869 70.	1870-71.
	ft.	ft.	ft.
A_0=	7·1488	7·2908	7·2644
R_1	0·0718	0·0712	0·0750
ϵ_1	176°·57	187°·50	162°·29
R_2	0·9323	0·9425	0·9230
ϵ_2	322°·72	323°·68	323°·68
R_3	......	......	......
ϵ_3	......	......	......
R_4	very small	very small	0·0141
ϵ_4	......	......	355°·95
R_6	......	......	......
ϵ_6	......	......	......

M. Speed of semidiurnal $2(\gamma-\sigma)$.

	1868-69.	1869-70.	1870-71.
I=	19°·6	21°·2	23°·0
	ft.	ft.	ft.
R_1	0·018	......	0·0510
ϵ_1	271°·60	......	329°·18
R_2	2·5859	2 4974	2·4717
ϵ_2	295° 78	297°·24	296° 62
R_3	0 0439	0·0382	0·0492
ϵ_3	335°·18	336°·09	325°·46
R_4	0·0169	0·0284	0·0242
ϵ_4	47°·04	30°·41	31°·70
R_6	0 0444	0·0494	0·0445
ϵ_6	225° 91	215°·16	224°·55

K. Speed of semidiurnal (2γ).

	1868-69.	1869-70.	1870-71.
R_1	1·1669	1·1907	1·2392
ϵ_1	142°·87	144°·73	146° 87
R_2	0·2389	0·2355	0 2467
ϵ_2	340°·25	330°·57	330°·94

O. Speed $(\gamma-2\sigma)$.

	1868-69.	1869-70.	1870-71.
R_1	0·5688	0·5905	0·6164
ϵ_1	308°·87	309°·94	306°·97

P. Speed $(\gamma-2\eta)$.

	1868-69.	1869-70.	1870-71.
R_1	0·3755	0·3850	0·3746
ϵ_1	316°·35	320°·27	314°·97

	J. Speed $(\gamma+\sigma-\varpi)$.			Q. Speed $(\gamma-3\sigma+\varpi)$.		
	1868–69.	1869–70.	1870–71.	1868–69.	1869–70.	1870–71.
	ft.	ft.	ft.	ft.	ft.	ft.
R_1	0·0800	0·0434	0·0686	0·1110	0·1100	0·1354
ϵ_1	178°·58	165°·88	141°·37	308°·23	320°·34	313°·05

	L. Speed $(2\gamma-\sigma-\varpi)$.			N. Speed $(2\gamma-3\sigma+\varpi)$.		
	1868–69.	1869–70.	1870–71.	1868–69.	1869–70.	1870–71.
R_2	0·0804	0·0365	0·0824	0·6221	0·5987	0·5766
ϵ_2	108°·67	140°·69	129°·68	280°·31	282°·83	281°·35

	λ. Speed $(2\gamma-\sigma+\varpi-2\eta)$.			ν. Speed $(2\gamma-3\sigma-\varpi+2\eta)$.		
	1868–69.	1869–70.	1870–71.	1868–69.	1869–70.	1870–71.
R_2	0·0613	0·0381	0·0432	0·1955	0·0832	0·0814
ϵ_2	156°·46	91°·56	30°·71	255°·63	224°·40	345°·20

	μ or 2MS. Speed $(2\gamma-4\sigma+2\eta)$.				MS. Speed $(4\gamma-2\sigma-2\eta)$.		
	1868–69.	1869–70.	1870–71.		1868–69.	1869–70.	1870–71.
R_2	0·0703	0·0333	0·0714	R_4	0·0173	0·0236	0·0311
ϵ_2	269°·99	227°·72	304°·53	ϵ_4	216°·79	181°·30	326°·55

	R. Speed $(2\gamma-\eta)$.	T. Speed $(2\gamma-3\eta)$.
	1868–69 and 1869–70.	1868–69 and 1869–70.
R_2	0·0353	0·1108
ϵ_2	12°·04	38°·96

43. Long-period Tides.

	1868–69.	1869–70.	1870–71.	
	ft.	ft.	ft.	
R	0·115	0·179	0·162	Solar annual (elliptic) tide. Speed (η).
ϵ	43°·96	80°·20	107°·11	
R	0·198	0·059	0·062	Solar semiannual (declinational) tide.
ϵ	81°·98	116°·93	69°·69	Speed (2η).
R	0·076	0·043	0·032	Lunar monthly (elliptic) tide.
ϵ	247°·73	175°·27	115°·90	Speed $(\sigma-\varpi)$.
R	0·038	0·064	0·035	Lunar fortnightly (declinational) tide.
ϵ	335°·40	333°·91	283° 22	Speed (2σ).
R	0·009	0·075	0·058	Lunisolar synodic fortnightly (shallow-water)
ϵ	326°·19	16°·98	156°·62	tide. Speed $2(\sigma-\eta)$.

44. The epochs are reckoned from the meridian of Kurrachee for the short-period tides, and for the long-period tides from the time when the respective argument of each tide equals 0°·0,—*i. e.* for the solar annual and semiannual tides from the mean vernal equinox, for the lunar monthly tide from the mean perigee, for the lunar fortnightly from the time when the moon's mean longitude equals 0° and 180°, and for the synodic fortnightly from the mean new and full moons.

45. In addition to the foregoing reductions, a selection has been made from the tide-observations taken during the construction of the Portland Breakwater, under the direction of Sir John Coode, from 1851 to 1871. The years selected for reduction were 1851 and 1871, being the first and last years of the observations at present taken, and the years 1857 and 1866, being the

years in which the moon's declination had attained its maximum and minimum respectively. The peculiarity of the tide here gives rise to a considerable number of important compound shallow-water tide-components, which has led indirectly to their evaluation at Liverpool and Ramsgate, through this clue to their probable existence having been found. It is probable that others besides those already found may exist, and of which a further examination of the tide-curve may indicate their periods. The epochs of the tide-components are referred to the meridian of Greenwich, similarly to the previously analyzed tides of Ramsgate and Liverpool.

Portland Breakwater (Lat. 50°·5 N., Long. 9^{m}·8 W. from Greenwich).

	S. Speed of semidiurnal $2(\gamma-\eta)$.				M. Speed of semidiurnal $2(\gamma-\sigma)$.			
	1851.	1857.	1866.	1870.	1851.	1857.	1866.	1870.
	ft.	ft.	ft.	ft.	I=21°·6	28°·5	18°·5	22°·2
A_0	=7·0766	7·0054	7·1114	6·9860	ft.	ft.	ft.	ft.
R_1	0·0742	0·0310	0·0255	0·0146	0·0178	0·0071	0·0348	0·0240
ϵ_1	83°·85	97°·69	90°·56	82°·80	244°·18	247°·54	333°·72	291°·01
R_2	1·0761	1·0757	1·0903	1·0551	2·1450	2·0271	1·9824	2·0943
ϵ_2	243°·31	246°·64	244°·85	241°·39	195°·13	196°·57	194°·80	194°·48
R_3	......	......	......	......	0·0300	0·0425	0·0481	0·0264
ϵ_3	......	......	......	......	174°·36	195°·17	188°·10	169°·31
R_4	0·0120	0·0096	0·0163	0·0104	0·4556	0·4960	0·4725	0·4680
ϵ_4	193°·14	185°·04	167°·58	196°·26	32°·41	41°·90	30°·07	32°·90
R_6	......	......	......	......	0·2217	0·1944	0·2178	0·2106
ϵ_6	......	......	......	......	73°·07	79°·36	67°·07	71°·02
R_8	......	......	......	......	0·0136	0·0146	0·0112	0·0090
ϵ_8	......	......	......	......	61°·70	45°·78	38°·83	65°·50

K. Speed of semidiurnal (2γ).

	1851.	1857.	1866.	1870.
R_1	0·2705	0·3245	0·2597	0·2995
ϵ_1	211°·08	205°·55	202°·97	212°·91
R_2	0·2768	0·3854	0·2365	0·2590
ϵ_2	253°·95	243°·01	232°·12	252°·85

	O. Speed $(\gamma-2\sigma)$.				P. Speed $(\gamma-2\eta)$.			
	1851.	1857.	1866.	1870.	1851.	1857.	1866.	1870.
R_1	0·1536	0·1919	0·1255	0·1605	0·0957	0·1179	0·1077	0·1082
ϵ_1	249°·88	266°·54	262°·25	251°·77	20°·82	18°·09	14°·67	17°·64

	L. Speed $(2\gamma-\sigma-\varpi)$.				N. Speed $(2\gamma-3\sigma+\varpi)$.			
	1851.	1857.	1866.	1870.	1851.	1857.	1866.	1870.
R_2	0·2054	0·1009	0·1544	0·1723	0·4734	0·4454	0·5182	0·4890
ϵ_2	313°·39	299°·73	296°·54	288°·43	185°·73	185°·66	185°·85	186°·31

	λ. Speed $(2\gamma-\sigma+\varpi-2\eta)$.				ν. Speed $(2\gamma-3\sigma-\varpi+2\eta)$.			
	1851.	1857.	1866.	1870.	1851.	1857.	1866.	1870.
R_2	0·1045	0·0560	0·0832	0·0901	0·0950	0·1203	0·1248	0·1234
ϵ_2	295°·19	288°·69	314°·10	294°·24	197°·77	118°·79	109°·00	136°·92

	μ or 2MS. Speed $(2\gamma-4\sigma+2\eta)$.				2SM. Speed $(2\gamma+2\sigma-4\eta)$.			
	1851.	1857.	1866.	1870.	1851.	1857.	1866.	1870.
	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.
R_2	0·3900	0·3719	0·3773	0·3756	0·0512	0·0687	0·0639	0·0512
ϵ_2	200°·49	199°·54	192°·80	196°·61	349°·22	6°·21	348°·42	344°·04

	MS. Speed $(4\gamma-2\sigma-2\eta)$.				3MS. Speed $(4\gamma-6\sigma+2\eta)$.			
	1851.	1857.	1866.	1870.	1851.	1857.	1866.	1870.
R_4	0·2660	0·2655	0·2618	0·2831	0·0517	0·0461	0·0391	0·0263
ϵ_4	88°·15	94°·45	89°·43	93°·26	132°·19	135°·62	136°·74	134°·50

46. The complete separation of the mean lunar and mean solar semidiurnal tides in the foregoing analysis, together with the respective epochs of each tide, furnishes a ready means of finding the time of spring-tides or the time at which the two tides are exactly the same in phase. If we take, for instance, the respective epochs of these tides as given (§ 25) for Ramsgate, we find that the mean solar semidiurnal tide attains its maximum when *twice* the mean sun's hour-angle, or angular distance from the meridian, is 32°·70. Similarly the mean lunar semidiurnal tide attains its maximum when *twice* the mean moon's hour-angle is 339°·43. Dividing the difference between these two epochs by *twice* the difference between their respective mean daily motions, we obtain an interval which represents the time at which the two tides are coincident after the two bodies were in conjunction. The difference between the mean daily motions of the moon and sun is 12°·191 per day. The result thus obtained for Ramsgate is

$$\frac{360^\circ+32^\circ\cdot70-339^\circ\cdot43}{2\times12^\circ\cdot191}=\frac{53^\circ\cdot27}{24^\circ\cdot382}=2\cdot185 \text{ days}.$$

47. Treating the solar diurnal declinational tide (P) and the lunar diurnal declinational tide (O) in a similar way, we obtain the interval after the conjunction of the two bodies at which these tides are coincident in phase. Thus, for instance, we find (§ 25) for Ramsgate

$$\frac{262^\circ\cdot58-99^\circ\cdot34}{2\times12^\circ\cdot191}=\frac{163^\circ\cdot24}{24^\circ\cdot382}=6\cdot695 \text{ days}.$$

48. The lunar elliptic semidiurnal tides L and N, and the mean lunar semidiurnal tide M may also be similarly treated. The equilibrium theory gives

$$h\{\cos 2(\gamma-\sigma)t+\frac{7e}{2}\cos[2(\gamma-\sigma)t-\phi]-\frac{e}{2}\cos[2(\gamma-\sigma)t+\phi]\}$$

for the sum of the mean lunar semidiurnal and lunar elliptic semidiurnal tides, where h denotes the semi-range of the mean lunar semidiurnal tide, e the excentricity of the moon's orbit, and ϕ the longitude of the mean moon (M) reckoned from the perigee, or, astronomically speaking, the mean anomaly. We have

$$\phi=(\sigma-\varpi)(t-T)$$

if T denotes the time of perigee preceding t: and so the preceding becomes

$$h\{\cos 2(\gamma-\sigma)t+\frac{7e}{2}\cos[(2\gamma-3\sigma+\varpi)t+(\sigma-\varpi)\mathrm{T}]$$
$$-\frac{e}{2}\cos[(2\gamma-\sigma-\varpi)t-(\sigma-\varpi)\mathrm{T}]\}$$

or

$$h\{\cos 2(\gamma-\sigma)t+\frac{7e}{2}\cos[(2\gamma-3\sigma+\varpi)t+(\sigma-\varpi)\mathrm{T}]$$
$$+\frac{e}{2}\cos[(2\gamma-\sigma-\varpi)t+180^\circ-(\sigma-\varpi)\mathrm{T}]\},$$

showing that $t=\mathrm{T}$ is the time of coincidence of the M and N tides, and the time of opposition of the M and L tides. Let

$$\mathrm{R}_2\cos\{2(\gamma-\sigma)t-\epsilon_2\}+\mathrm{R}_2'\cos[(2\gamma-3\sigma+\varpi)t-\epsilon_2']$$
$$-\mathrm{R}_2''\cos[(2\gamma-\sigma-\varpi)t-\epsilon_2''+180^\circ]$$

be the expression for these constituents derived from observation. For the times of coincidence we have

M and N observation, $2(\gamma-\sigma)t-\epsilon_2=(2\gamma-3\sigma+\varpi)t-\epsilon_2'$,

giving $t=\dfrac{\epsilon_2-\epsilon_2'}{\sigma-\varpi}$;

and therefore the *delay* $=\dfrac{\epsilon_2-\epsilon_2'}{\sigma-\varpi}-\mathrm{T}$:

similarly the *delay* of opposition of the M and L observed tides, after the opposition of the corresponding equilibrium tides, is

$$\frac{\epsilon_2''-\epsilon_2+180^\circ}{\sigma-\varpi}-\mathrm{T}.$$

If, however, the corrected epochs are used, the term T should be omitted. Thus for Ramsgate (§ 25) we have for the *delay* of coincidence of phase between the M and N tides

$$\frac{339^\circ{\cdot}43-310^\circ{\cdot}31}{13^\circ{\cdot}065}=\frac{29^\circ{\cdot}12}{13^\circ{\cdot}065}=2{\cdot}229 \text{ days } \textit{after} \text{ the moon's perigee;]}$$

and for the *delay* of opposition of phase between the M and L tides

$$\frac{186^\circ{\cdot}28-339^\circ{\cdot}43+180^\circ}{13^\circ{\cdot}065}=\frac{26^\circ{\cdot}85}{13^\circ{\cdot}065}=2{\cdot}056 \text{ days } \textit{after} \text{ the moon's perigee,}$$

The solar elliptic semidiurnal tides R and T may be referred in a similar manner to the mean solar semidiurnal tide (S).

49. It is here worthy of remark, that the larger (N) lunar elliptic semidiurnal equilibrium-tide (as indicated above) is *seven* times the value of the smaller component (L); but on reference to the foregoing results it will be found that the proportion between the actual components for English ports is about $3\frac{1}{2}$ to 1. The cause of this discrepance has not yet been discovered: as will be seen subsequently (§ 51), the deduced value of the smaller component L is too large when compared with its equilibrium-

theoretical value for nearly all places. On the other hand, the equilibrium-theoretical ratio is fairly approximated to in the values found for Fort Point and Kurrachee.

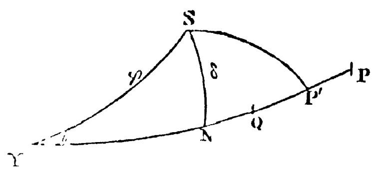
50. The following Table exhibits the times of coincidence and opposition of phase of some of the chief tides. The values are deduced from the mean of the results when more than one year's observations have been analyzed.

	Coincidence of phase of S and M	Coincidence of phase of P and O	Coincidence of phase of M and N	Opposition of phase of M and L
	After Moon's Syzygies.		After Moon's Perigee.	
	d	d	d	d
Liverpool. Lat. 53°·40 N., long. 0^h·20 W.	1·850	5·796	1·534	0·356
Ramsgate. Lat. 51°·3 N., long. 0^h·00 E.	2·185	6·695	2·229	2·056
Portland Breakwater. Lat. 50°·5 N., long. 0^h·16 W.	2·001	4·930	0·716	−5·796
Kurrachee (India). Lat. 24°·9 N., long. 4^h·47 E.	1·100	0·353	1·152	0·750
Bombay (India). Lat. 18°·95 N., long. 4^h·86 E.	1·070	......	1·846	−4·201
Fort Point (California). Lat. 37°·67 N., long. 8^h·15 W.	0·214	0·790	2·024	0·126
Cat Island (Gulf of Mexico). Lat. 30°·23 N., long. 5^h·94 W.	0·535	0·260	−1·747	2·422

The sign − indicates that the phenomenon occurs *before* the moon's perigee.

The following is the investigation of the formula for semidiurnal and semidiurnal declinational tides:—

Let ♈P and ♈S be the great circles in which a geocentric spherical surface is cut by the earth's equator and by the plane of the orbit of sun or moon. When the moon is considered, ♈ will be approximately the first point of Aries. It is, of course, rigorously so for the sun.



Drawing SN perpendicular to ♈P, we have SN$=\delta$, the declination. Let S♈P$=i$, being the inclination of the orbit to the equator. Suppose now Q and P to be points of the equator in which it is cut by the meridian through the crests of the semidiurnal equilibrium tide, and the meridian through the place for which the equilibrium tide is to be expressed. If s denote the equilibrium semidiurnal variation of tide-height, we find readily, from § 808 (23) of Thomson and Tait's 'Natural Philosophy'

$$s=c\cos^2 l\cos^2\delta\cos(2\times \mathrm{QP}),$$

where c denotes a constant for each place. Take P′ so that PP′=QN, and join SP′.

We have

$$s=c\cos^2\delta\cos(2\times\mathrm{NP}')=c\cos^2\delta(2\cos^2\mathrm{NP}'-1).$$

But

$$\cos^2\delta\cos^2\mathrm{NP}'=\cos^2\mathrm{SP}'=(\cos\Upsilon\mathrm{S}\cos\Upsilon\mathrm{P}'+\sin\Upsilon\mathrm{S}\sin\Upsilon\mathrm{P}'\cos i)^2$$

$$=\left\{\frac{1+\cos i}{2}\cos(\Upsilon\mathrm{P}'-\Upsilon\mathrm{S})+\frac{1-\cos i}{2}\cos(\Upsilon\mathrm{P}'+\Upsilon\mathrm{S})\right\}^2$$

$$=\left(\frac{1+\cos i}{2}\right)^2\cos^2(\Upsilon\mathrm{P}'-\Upsilon\mathrm{S})+\frac{\sin^2 i}{2}(\cos^2\Upsilon\mathrm{P}'-\sin^2\Upsilon\mathrm{S})+\left(\frac{1-\cos i}{2}\right)^2\cos^2(\Upsilon\mathrm{P}'+\Upsilon\mathrm{S})$$

$$=\tfrac{1}{2}\left\{\left(\frac{1+\cos i}{2}\right)^2\cos 2(\Upsilon\mathrm{P}'-\Upsilon\mathrm{S})+\frac{\sin^2 i}{2}\cos 2\Upsilon\mathrm{P}'+\left(\frac{1-\cos i}{2}\right)^2\cos 2(\Upsilon\mathrm{P}'+\Upsilon\mathrm{S})-\sin^2\delta\right.$$
$$\left.+\left(\frac{1+\cos i}{2}\right)^2+\left(\frac{1-\cos i}{2}\right)^2+\frac{\sin^2 i}{2}\right\}$$

$$=\tfrac{1}{2}\left\{\left(\frac{1+\cos i}{2}\right)^2\cos 2(\Upsilon\mathrm{P}'-\Upsilon\mathrm{S})+\frac{\sin^2 i}{2}\cos 2\Upsilon\mathrm{P}'+\left(\frac{1-\cos i}{2}\right)^2\cos 2(\Upsilon\mathrm{P}'+\Upsilon\mathrm{S})+\cos^2\delta\right\}.$$

Hence

$$s=c\left\{\left(\frac{1+\cos i}{2}\right)^2\cos 2(\Upsilon\mathrm{P}'-\Upsilon\mathrm{S})+\frac{\sin^2 i}{2}\cos 2\Upsilon\mathrm{P}'+\left(\frac{1-\cos i}{2}\right)^2\cos 2(\Upsilon\mathrm{P}'+\Upsilon\mathrm{S})\right\}.\ (1)$$

If time be reckoned from the transit of the first point of Aries across the meridian of P′, we have

$$\Upsilon\mathrm{P}'=\gamma t$$

when the formula is applied to the solar tide, and for the lunar

$$\Upsilon\mathrm{P}'=\gamma t-\Omega,$$

where Ω denotes the right ascension of the intersection of the moon's orbit with the earth's equator, from the first point of Aries. For the solar tide ΥS is the sun's longitude, and for the lunar ΥS is equal to the moon's longitude with a correction depending on Ω. Hence, in the two cases respectively, we have

$$\Upsilon\mathrm{S}=\eta t+\epsilon+\mathrm{P},\quad \Upsilon\mathrm{S}=\sigma t+\epsilon'+\mathrm{Q},\ \ldots\ldots\ldots\ (2)$$

where ϵ, ϵ' denote the longitudes of the two bodies at the time $t=0$, P the sun's elliptic inequality of longitude, and Q the moon's elliptic and inclinational inequality of longitude. For the mean semidiurnal and the declinational semidiurnal tides we neglect these inequalities, and so find

$$\left.\begin{array}{l}
\text{(Solar)}\\
s=c\left\{\left(\frac{1+\cos\omega}{2}\right)^2\cos 2[(\gamma-\eta)t-\epsilon]+\frac{\sin^2\omega}{2}\cos 2\gamma t+\left(\frac{1-\cos\omega}{2}\right)^2\cos 2[(\gamma+\eta)t+\epsilon]\right\},\\
\text{where } \omega \text{ denotes the obliquity of the ecliptic, and}\\
\text{(Lunar)}\\
s'=c'\left\{\left(\frac{1+\cos i}{2}\right)^2\cos 2[(\gamma-\sigma)t-\epsilon']+\frac{\sin^2 i}{2}\cos 2\gamma t+\left(\frac{1-\cos i}{2}\right)^2\cos 2[(\gamma+\sigma)t+\epsilon']\right\}.
\end{array}\right\}\ .\ (3)$$

Denoting by E, S, M the masses of the earth, the sun, and the moon, by ϖ, ϖ' the parallaxes of the sun and moon, expressed in radial measure $\left[i.e.\ \frac{\text{arc}}{\text{radius}}\right]$, by a the earth's radius, and by l the latitude of the place,

and neglecting the influence of land ($\mathfrak{A}$, $\mathfrak{B}$), we have [Thomson and Tait, §§ 808, (18), (23)]

$$c=\frac{3S}{4E}\varpi^3 a\cos^2 l \quad\text{and}\quad c'=\frac{3M}{4E}\varpi'^3 a\cos^2 l. \quad . \;.\;.\;.\;.\;.\;.\;. \quad (4)$$

Using these and (2), with the notation of (3) in (1), we find

$$s+s'=\frac{3a}{4}\cos^2 l\left\{\frac{\varpi^3 S}{E}\left[\left(\frac{1+\cos\omega}{2}\right)^2\cos\left[2(\gamma-\eta)t-2\epsilon-2P\right]+\frac{\sin^2\omega}{2}\cos 2\gamma t\right.\right.$$
$$+\left(\frac{1-\cos\omega}{2}\right)^2\cos\left[2(\gamma+\eta)t+2\epsilon+2P\right]\Big]$$
$$+\frac{\varpi'^3 M}{E}\left[\left(\frac{1+\cos i}{2}\right)^2\cos 2[(\gamma-\sigma)t-\Omega-\epsilon'-Q]+\frac{\sin^2 i}{2}\cos 2(\gamma t-\Omega)\right.$$
$$\left.\left.+\left(\frac{1-\cos i}{2}\right)^2\cos 2[(\gamma+\sigma)t-\Omega+\epsilon'+Q]\right]\right\} \quad . \;.\;.\;.\;.\;.\;.\;. \quad (5)$$

as the rigorous expression for the semidiurnal equilibrium tide-height, on the supposition of no dry land, or of such a distribution as to make $\mathfrak{A}=0$ and $\mathfrak{B}=0$. By taking the expressions given by physical astronomy for ϖ, P, ϖ', i, Ω, and Q, and expanding in series of simple harmonic functions of the time, it is easy to obtain, in the form proper for the harmonic analysis, a complete expression for the whole astronomical semidiurnal tide-generating influence.

The terms of (3) or (5), containing the factors $\left(\frac{1-\cos\omega}{2}\right)^2$ and $\left(\frac{1-\cos i}{2}\right)^2$, are, on account of these factors, necessarily very small. They show semidiurnal constituents with arguments $2(\gamma+\eta)t$ (solar) and $2(\gamma+\sigma)t$ (lunar), which have not hitherto been investigated from observation, but which, for the case of the moon, and particularly in years when i is large, may be quite sensible.

51. The Table on the opposite page exhibits the comparative values of the analyzed and equilibrium-theoretical semidiurnal tides referred to the mean lunar semidiurnal tide as unity. The epochs of all of these tides are expressed in hour-angles of mean solar time, and are referred to the meridian of the place, except for Liverpool, Ramsgate, and Portland Breakwater, which are referred to the meridian of Greenwich.

52. The following will illustrate the method at present employed in the comparison between the actual tide-heights as recorded and the heights as furnished by the evaluated tide-constants. The residual differences (which include instrumental errors of every description) show the amount of precision arrived at from the tide-components included in the analysis, and are useful as a guide for the introduction of new arguments and the consequent evaluation of new tide-components. The Tables are based on the analyzed values of the tide-components of Kurrachee for the year 1868–69 alone, excepting the R and T solar elliptic semidiurnal tides, which are the results of 1868–1869 and following year.

In order to facilitate the computations of the heights, Tables showing the value of the tide above or below mean level for each 15° of hour-angle for the S tide should be formed, or for a less interval if it is contemplated computing the tide-heights for more frequent intervals than each integral mean solar hour, and for every degree of the M tide on account of the magnitude of R_2 of this tide, and for every few degrees for the rest of the tide-components.

		Mean Lunar Semidiurnal.	Lunar Elliptic Semidiurnal.		*Evection* Semidiurnal.		*Variation* Semi-diurnal.	Mean Solar Semi-diurnal.	Solar Elliptic Semidiurnal.		Lunisolar Declinational Semidiurnal.
		M	L	N	λ	ν	μ	S	R	T	K
Periods		$12^{h}\cdot4206$	$12^{h}\cdot1916$	$12^{h}\cdot6584$	$12^{h}\cdot2218$	$12^{h}\cdot6260$	$12^{h}\cdot8718$	$12^{h}\cdot0000$	$11^{h}\cdot9836$	$12^{h}\cdot0165$	$11^{h}\,9672$
Equilibrium-theoretical values. (Moon to sun $=2\cdot1$ to 1.)	R =	1·000	0·027	0·192	0·007	0·037	0·022	0·476	0·004	0·028	0·127
	Time of maximum =	$0^{h}\cdot00$	$0^{h}\cdot00$	$0^{h}\cdot00$	$0^{h}\cdot00$	$0^{h}\cdot00$	$0^{h}\cdot00$	$0^{h}\,00$	$0^{h}\cdot00$	$0^{h}\cdot00$	$0^{h}\cdot00$
Liverpool. Lat. $53^{\circ}\cdot40$ N., long. $0^{h}\cdot20$ W.	R =	1·000	0·054	0·191	0·023	0·053	0·026	0·315	0·009	0·023	0·090
	Time of maximum =	$11^{h}\cdot27$	$11^{h}\cdot22$	$10^{h}\cdot74$	$11^{h}\cdot42$	$10^{h}\cdot23$	$1^{h}\cdot40$	$0^{h}\cdot39$	$10^{h}\cdot87$	$1^{h}\cdot75$	$0^{h}\cdot09$
Ramsgate. Lat. $51^{\circ}\cdot3$ N., long. $0^{h}\cdot09$ E.	R =	1·000	0·061	0·176	0·028	0·056	0·042	0·298	......	......	0·070
	Time of maximum =	$11^{h}\cdot71$	$0^{h}\cdot20$	$10^{h}\cdot91$	$11^{h}\cdot88$	$11^{h}\cdot51$	$3^{h}\cdot00$	$1^{h}\cdot09$	......	......	$0^{h}\cdot35$
Portland Breakwater. Lat. $50^{\circ}\cdot5$ N., long $0^{h}\cdot16$ W.	R =	1·000	0·077	0·233	0·04	0·056	0·184	0·521	......	......	0·127
	Time of maximum =	$6^{h}\,70$	$4^{h}\cdot08$	$6^{h}\cdot54$	$4^{h}\,01$	$4^{h}\cdot93$	$7^{h}\cdot06$	$8^{h}\cdot14$	......	......	$8^{h}\cdot16$
Kurrachee. Lat. $24^{\circ}\cdot9$ N., long. $4^{h}\cdot47$ E.	R =	1·000	0·026	0·238	0·019	0·048	0·023	0·371	0·014	0·044	0·102
	Time of maximum =	$10^{h}\cdot23$	$10^{h}\,38$	$9^{h}\cdot90$	$9^{h}\cdot26$	$9^{h}\cdot65$	$9^{h}\cdot56$	$10^{h}\,78$	$6^{h}\cdot39$	$1^{h}\cdot30$	$11^{h}\cdot10$
Bombay. Lat. $18^{\circ}\cdot95$ N., long. $4^{h}\cdot86$ E.	R =	1·000	0·073	0·225	......	......	......	0·419	......	......	0·203
	Time of maximum =	$2^{h}\cdot05$	$0^{h}\cdot35$	$1^{h}\cdot24$	......	......	......	$2^{h}\cdot35$	......	......	$6^{h}\cdot28$
Fort Point (California). Lat. $37^{\circ}\cdot67$ N., long. $8^{h}\cdot15$ W.	R =	1·000	0·030	0·221	0·015	0·038	0·017	0·236	0·005	0·009	0·070
	Time of maximum =	$11^{h}\cdot40$	$11^{h}\cdot25$	$10^{h}\cdot68$	$11^{h}\cdot64$	$10^{h}\cdot63$	$7^{h}\cdot99$	$11^{h}\cdot18$	$11^{h}\cdot45$	$9^{h}\cdot28$	$10^{h}\cdot05$
Cat Island (Gulf of Mexico). Lat. $30^{\circ}\cdot23$ N., long. $5^{h}\cdot94$ W.	R =	1·000	0·099	0·225	......	......	......	0·567	......	......	0·170
	Time of maximum =	$0^{h}\cdot37$	$1^{h}\cdot43$	$1^{h}\cdot18$	......	......	......	$0^{h}\,79$	......	......	$9^{h}\cdot60$

(1) **S.**—Solar Semidiurnal tide (including effect of solar elliptic diurnal).

$$h=R_1 \cos\{(\gamma-\eta)t-\epsilon_1\}+R_2 \cos\{(2\gamma-\eta)t-\epsilon_2\}$$
$$=0\cdot072 \cos\{(\gamma-\eta)t-176^\circ\cdot57\}+0\cdot932 \cos\{2(\gamma-\eta)t-322^\circ\cdot72\}$$

a	b	c	d	A	B	h'
$(\gamma-\eta)t$	$(\gamma-\eta)t-\epsilon_1$	$\cos b$	$c\times R_1$	$d+R_1$	(from below)	A+B
°	°		ft.	ft.	ft.	ft.
0	183·43	−·998	−·072	·000	1·674	1·674
15	198·43	−·949	−·069	·003	1·292	1·295
30	213·43	−·835	−·060	·012	0·814	0·826
45	228·43	−·663	−·048	·024	0·367	0·391
60	243·43	−·447	−·032	·040	0·073	0·113
75	258·43	−·201	−·014	·058	0·007	0·065
90	273·43	+·060	+·004	·076	0·190	0·266
105	288·43	+·316	+·023	·095	0·572	0·667
120	303·43	+·551	+·040	·112	1·050	1·162
135	318·43	+·748	+·054	·126	1·497	1·623
150	333·43	+·894	+·064	·136	1·791	1·927
165	348·43	+·980	+·071	·143	1·857	2·000
180	3·43	+·998	+·072	·144	1·674	1·818
195	18·43	+·949	+·069	·141	1·292	1·433
210	33·43	+·835	+·060	·132	0·814	0·946
225	48·43	+·663	+·048	·120	0·367	0·487
240	63·43	+·447	+·032	·104	0·073	0·177
255	78·43	+·201	+·014	·086	0·007	0·093
270	93·43	−·060	−·004	·068	0·190	0·258
285	108·43	−·316	−·023	·049	0·572	0·621
300	123·43	−·551	−·040	·032	1·050	1·082
315	138·43	−·748	−·054	·018	1·497	1·515
330	153·43	−·894	−·064	·008	1·791	1·799
345	168·43	−·980	−·071	·001	1·857	1·858

a	b	c	d	B
$2(\gamma-\eta)t$	$2(\gamma-\eta)t-\epsilon$	$\cos b$	$c\times R_2$	$d+R_2$
°	°		ft.	ft.
0	37·28	+·796	+·742	1·674
30	67·28	+·386	+·360	1·292
60	97·28	−·127	−·118	0·814
90	127·28	−·606	−·565	0·367
120	157·28	−·922	−·859	0·073
150	187·28	−·992	−·925	0·007
180	217·28	−·796	−·742	0·190
210	247·28	−·386	−·360	0·572
240	277·28	+·127	+·118	1·050
270	307·28	+·606	+·565	1·497
300	337·28	+·922	+·859	1·791
330	7·28	+·992	+·925	1·857

The values of R_1 and R_2 have been added to each value of h to make all the heights positive, and therefore the sum of R_1 and R_2, or 1·004, will have to be subtracted in the calculations of the heights on account of these tides. Similarly, in the other Tables the value of R has in each case been added (except for the lunisolar diurnal and semidiurnal tides, for which tides 1·12 foot instead of 1·41 foot has been applied); the augmented values are indicated by the symbol h'.

Instead, therefore, of the mean height being added to the sum of the values of h' in the formation of the tide-heights, the difference between the mean height and the sum of the whole of the tide-components is to be applied. Care should be taken, in reading off the tide-heights in the first instance, to choose a datum-line sufficiently low, in order to secure this difference being positive.

Tables for the other tide-components have been similarly formed, and are here given:—

(2) **M.**—Lunar Semidiurnal (including elliptic diurnal, terdiurnal, &c.).

$$h=0{\cdot}018\cos\{(\gamma-\sigma)t-271^\circ{\cdot}60\}+2{\cdot}586\cos\{2(\gamma-\sigma)t-295^\circ{\cdot}78\}$$
$$+0{\cdot}044\cos\{3(\gamma-\sigma)t-335^\circ{\cdot}18\}+0{\cdot}017\cos\{4(\gamma-\sigma)t-47^\circ{\cdot}04\}$$
$$+0{\cdot}044\cos\{6(\gamma-\sigma)t-225^\circ{\cdot}91\}.$$

$(\gamma-\sigma)t$	h'	$(\gamma-\sigma)t$	h'	$(\gamma-\sigma)t$	h'	$(\gamma-\sigma)t$	h'	$(\gamma-\sigma)t$	h'	$(\gamma-\sigma)t$	h'
°	ft.	°	ft.	°	ft.	°	ft.	°	ft.	°	ft.
0	3·86	60	·03	120	4·16	180	3·78	240	·14	300	4·11
1	3·77	61	·03	121	4·23	181	3·69	241	·14	301	4·18
2	3·68	62	·04	122	4·30	182	3·61	242	·15	302	4·25
3	3·60	63	·06	123	4·36	183	3·52	243	·16	303	4·32
4	3·51	64	·08	124	4·43	184	3·44	244	·18	304	4·39
5	3·42	65	·10	125	4·49	185	3·35	245	·20	305	4·45
6	3·33	66	·12	126	4·55	186	3·27	246	·22	306	4·51
7	3·24	67	·15	127	4·61	187	3·18	247	·24	307	4·57
8	3·15	68	·18	128	4·66	188	3·09	248	·27	308	4·63
9	3·06	69	·22	129	4·72	189	3·01	249	·30	309	4·69
10	2·97	70	·26	130	4·77	190	2·92	250	·34	310	4·75
11	2·88	71	·30	131	4·82	191	2·83	251	·38	311	4·80
12	2·79	72	·34	132	4·87	192	2·75	252	·42	312	4·85
13	2·69	73	·39	133	4·91	193	2·66	253	·47	313	4·90
14	2·60	74	·45	134	4·96	194	2·58	254	·51	314	4·95
15	2·52	75	·50	135	5·00	195	2·49	255	·57	315	4·99
16	2·43	76	·56	136	5·04	196	2·41	256	·62	316	5·04
17	2·34	77	·62	137	5·07	197	2·32	257	·68	317	5·07
18	2·25	78	·69	138	5·10	198	2·24	258	·74	318	5·11
19	2·16	79	·76	139	5·14	199	2·16	259	·80	319	5·15
20	2·07	80	·82	140	5·16	200	2·08	260	·87	320	5·18
21	1·99	81	·90	141	5·19	201	2·00	261	·93	321	5·21
22	1·90	82	·97	142	5·21	202	1·92	262	1·00	322	5·23
23	1·82	83	1·05	143	5·23	203	1·84	263	1·08	323	5·26
24	1·74	84	1·13	144	5·24	204	1·76	264	1·15	324	5·28
25	1·65	85	1·21	145	5·26	205	1·68	265	1·23	325	5·30
26	1·57	86	1·29	146	5·27	206	1·61	266	1·30	326	5·31
27	1·49	87	1·37	147	5·27	207	1·53	267	1·38	327	5·32
28	1·42	88	1·45	148	5·28	208	1·46	268	1·46	328	5·33
29	1·34	89	1·54	149	5·28	209	1·39	269	1·54	329	5·33
30	1·26	90	1·63	150	5·27	210	1·32	270	1·63	330	5·33
31	1·19	91	1·72	151	5·27	211	1·25	271	1·71	331	5·33
32	1·11	92	1·81	152	5·26	212	1·18	272	1·80	332	5·32
33	1·05	93	1·89	153	5·25	213	1·11	273	1·88	333	5·31
34	·98	94	1·98	154	5·23	214	1·05	274	1·97	334	5·30
35	·91	95	2·08	155	5·21	215	·99	275	2·05	335	5·28
36	·84	96	2·17	156	5·19	216	·92	276	2·14	336	5·26
37	·78	97	2·25	157	5·16	217	·86	277	2·23	337	5·24
38	·72	98	2·35	158	5·13	218	·81	278	2·32	338	5·21
39	·66	99	2·44	159	5·10	219	·75	279	2·40	339	5·18
40	·60	100	2·53	160	5·06	220	·69	280	2·49	340	5·14
41	·55	101	2·62	161	5·02	221	·64	281	2·58	341	5·11
42	·49	102	2·71	162	4·98	222	·59	282	2·66	342	5·07
43	·44	103	2·80	163	4·93	223	·55	283	2·75	343	5·02
44	·39	104	2·89	164	4·88	224	·50	284	2·84	344	4·97
45	·35	105	2·97	165	4·83	225	·45	285	2·92	345	4·92
46	·31	106	3·06	166	4·77	226	·41	286	3·01	346	4·87
47	·26	107	3·15	167	4·72	227	·38	287	3·09	347	4·81
48	·23	108	3·23	168	4·66	228	·34	288	3·18	348	4·75
49	·19	109	3·31	169	4·59	229	·31	289	3·26	349	4·69
50	·16	110	3·40	170	4·53	230	·28	290	3·34	350	4·62
51	·13	111	3·48	171	4·46	231	·25	291	3·43	351	4·56
52	·11	112	3·56	172	4·39	232	·22	292	3·51	352	4·49
53	·09	113	3·64	173	4·32	233	·20	293	3·59	353	4·42
54	·07	114	3·72	174	4·25	234	·18	294	3·66	354	4·34
55	·05	115	3·80	175	4·17	235	·17	295	3·74	355	4·26
56	·04	116	3·87	176	4·10	236	·15	296	3·82	356	4·19
57	·03	117	3·95	177	4·02	237	·15	297	3·89	357	4·11
58	·03	118	4·02	178	3·94	238	·14	298	3·97	358	4·02
59	·03	119	4·09	179	3·86	239	·14	299	4·04	359	3·94
60	·03	120	4·16	180	3·78	240	·14	300	4·11	360	3·86

Moon's max. dec. (1868 May to 1869 May) = 19° 7.

(1) **S.**—Solar Semidiurnal tide (including effect of solar elliptic diurnal).

$$h = R_1 \cos\{(\gamma-\eta)t-\epsilon_1\} + R_2 \cos\{(2\gamma-\eta)t-\epsilon_2\}$$
$$= 0{\cdot}072 \cos\{(\gamma-\eta)t - 176^\circ{\cdot}57\} + 0{\cdot}932 \cos\{2(\gamma-\eta)t - 322^\circ{\cdot}72\}$$

a $(\gamma-\eta)t$	b $(\gamma-\eta)t-\epsilon_1$	c $\cos b$	d $c\times R_1$ ft.	A $d+R_1$ ft.	B (from below) ft.	h' A+B ft.
°	°					
0	183·43	−·998	−·072	·000	1·674	1·674
15	198·43	−·949	−·069	·003	1·292	1·295
30	213·43	−·835	−·060	·012	0·814	0·826
45	228·43	−·663	−·048	·024	0·367	0·391
60	243·43	−·447	−·032	·040	0·073	0·113
75	258·43	−·201	−·014	·058	0·007	0·065
90	273·43	+·060	+·004	·076	0·190	0·266
105	288·43	+·316	+·023	·095	0·572	0·667
120	303·43	+·551	+·040	·112	1·050	1·162
135	318·43	+·748	+·054	·126	1·497	1·623
150	333·43	+·894	+·064	·136	1·791	1·927
165	348·43	+·980	+·071	·143	1·857	2·000
180	3·43	+·998	+·072	·144	1·674	1·818
195	18·43	+·949	+·069	·141	1·292	1·433
210	33·43	+·835	+·060	·132	0·814	0·946
225	48·43	+·663	+·048	·120	0·367	0·487
240	63·43	+·447	+·032	·104	0·073	0·177
255	78·43	+·201	+·014	·086	0·007	0·093
270	93·43	−·060	−·004	·068	0·190	0·258
285	108·43	−·316	−·023	·049	0·572	0·621
300	123·43	−·551	−·040	·032	1·050	1·082
315	138·43	−·748	−·054	·018	1·497	1·515
330	153·43	−·894	−·064	·008	1·791	1·799
345	168·43	−·980	−·071	·001	1·857	1·858

a $2(\gamma-\eta)t$	b $2(\gamma-\eta)t-\epsilon$	c $\cos b$	d $c\times R_2$ ft.	B $d+R_2$ ft.
°	°			
0	37·28	+·796	+·742	1·674
30	67·28	+·386	+·360	1·292
60	97·28	−·127	−·118	0·814
90	127·28	−·606	−·565	0·367
120	157·28	−·922	−·859	0·073
150	187·28	−·992	−·925	0·007
180	217·28	−·796	−·742	0·190
210	247·28	−·386	−·360	0·572
240	277·28	+·127	+·118	1·050
270	307·28	+·606	+·565	1·497
300	337·28	+·922	+·859	1·791
330	7·28	+·992	+·925	1·857

The values of R_1 and R_2 have been added to each value of h to make all the heights positive, and therefore the sum of R_1 and R_2, or 1·004, will have to be subtracted in the calculations of the heights on account of these tides. Similarly, in the other Tables the value of R has in each case been added (except for the lunisolar diurnal and semidiurnal tides, for which tides 1·12 foot instead of 1·41 foot has been applied); the augmented values are indicated by the symbol h'.

Instead, therefore, of the mean height being added to the sum of the values of h' in the formation of the tide-heights, the difference between the mean height and the sum of the whole of the tide-components is to be applied. Care should be taken, in reading off the tide-heights in the first instance, to choose a datum-line sufficiently low, in order to secure this difference being positive.

Tables for the other tide-components have been similarly formed, and are here given:—

(2) **M.**—Lunar Semidiurnal (including elliptic diurnal, terdiurnal, &c.).

$$h = 0{\cdot}018\cos\{(\gamma-\sigma)t - 271^\circ{\cdot}60\} + 2{\cdot}586\cos\{2(\gamma-\sigma)t - 295^\circ{\cdot}78\}$$
$$+ 0{\cdot}044\cos\{3(\gamma-\sigma)t - 335^\circ{\cdot}18\} + 0{\cdot}017\cos\{4(\gamma-\sigma)t - 47^\circ{\cdot}04\}$$
$$+ 0{\cdot}044\cos\{6(\gamma-\sigma)t - 225^\circ{\cdot}91\}.$$

$(\gamma-\sigma)t$	h'	$(\gamma-\sigma)t$	h'	$(\gamma-\sigma)t$	h'	$(\gamma-\sigma)t$	h'	$(\gamma-\sigma)t$	h'	$(\gamma-\sigma)t$	h'
°	ft.	°	ft.	°	ft.	°	ft.	°	ft.	°	ft.
0	3·86	60	·03	120	4·16	180	3·78	240	·14	300	4·11
1	3·77	61	·03	121	4·23	181	3·69	241	·14	301	4·18
2	3·68	62	·04	122	4·30	182	3·61	242	·15	302	4·25
3	3·60	63	·06	123	4·36	183	3·52	243	·16	303	4·32
4	3·51	64	·08	124	4·43	184	3·44	244	·18	304	4·39
5	3·42	65	·10	125	4·49	185	3·35	245	·20	305	4·45
6	3·33	66	·12	126	4·55	186	3·27	246	·22	306	4·51
7	3·24	67	·15	127	4·61	187	3·18	247	·24	307	4·57
8	3·15	68	·18	128	4·66	188	3·09	248	·27	308	4·63
9	3·06	69	·22	129	4·72	189	3·01	249	·30	309	4·69
10	2·97	70	·26	130	4·77	190	2·92	250	·34	310	4·75
11	2·88	71	·30	131	4·82	191	2·83	251	·38	311	4·80
12	2·79	72	·34	132	4·87	192	2·75	252	·42	312	4·85
13	2·69	73	·39	133	4·91	193	2·66	253	·47	313	4·90
14	2·60	74	·45	134	4·96	194	2·58	254	·51	314	4·95
15	2·52	75	·50	135	5·00	195	2·49	255	·57	315	4·99
16	2·43	76	·56	136	5·04	196	2·41	256	·62	316	5·04
17	2·34	77	·62	137	5·07	197	2·32	257	·68	317	5·07
18	2·25	78	·69	138	5·10	198	2·24	258	·74	318	5·11
19	2·16	79	·76	139	5·14	199	2·16	259	·80	319	5·15
20	2·07	80	·82	140	5·16	200	2·08	260	·87	320	5·18
21	1·99	81	·90	141	5·19	201	2·00	261	·93	321	5·21
22	1·90	82	·97	142	5·21	202	1·92	262	1·00	322	5·23
23	1·82	83	1·05	143	5·23	203	1·84	263	1·08	323	5·26
24	1·74	84	1·13	144	5·24	204	1·76	264	1·15	324	5·28
25	1·65	85	1·21	145	5·26	205	1·68	265	1·23	325	5·30
26	1·57	86	1·29	146	5·27	206	1·61	266	1·30	326	5·31
27	1·49	87	1·37	147	5·27	207	1·53	267	1·38	327	5·32
28	1·42	88	1·45	148	5·28	208	1·46	268	1·46	328	5·33
29	1·34	89	1·54	149	5·28	209	1·39	269	1·54	329	5·33
30	1·26	90	1·63	150	5·27	210	1·32	270	1·63	330	5·33
31	1·19	91	1·72	151	5·27	211	1·25	271	1·71	331	5·33
32	1·11	92	1·81	152	5·26	212	1·18	272	1·80	332	5·32
33	1·05	93	1·89	153	5·25	213	1·11	273	1·88	333	5·31
34	·98	94	1·98	154	5·23	214	1·05	274	1·97	334	5·30
35	·91	95	2·08	155	5·21	215	·99	275	2·05	335	5·28
36	·84	96	2·17	156	5·19	216	·92	276	2·14	336	5·26
37	·78	97	2·25	157	5·16	217	·86	277	2·23	337	5·24
38	·72	98	2·35	158	5·13	218	·81	278	2·32	338	5·21
39	·66	99	2·44	159	5·10	219	·75	279	2·40	339	5·18
40	·60	100	2·53	160	5·06	220	·69	280	2·49	340	5·14
41	·55	101	2·62	161	5·02	221	·64	281	2·58	341	5·11
42	·49	102	2·71	162	4·98	222	·59	282	2·66	342	5·07
43	·44	103	2·80	163	4·93	223	·55	283	2·75	343	5·02
44	·39	104	2·89	164	4·88	224	·50	284	2·84	344	4·97
45	·35	105	2·97	165	4·83	225	·45	285	2·92	345	4·92
46	·31	106	3·06	166	4·77	226	·41	286	3·01	346	4·87
47	·26	107	3·15	167	4·72	227	·38	287	3·09	347	4·81
48	·23	108	3·23	168	4·66	228	·34	288	3·18	348	4·75
49	·19	109	3·31	169	4·59	229	·31	289	3·26	349	4·69
50	·16	110	3·40	170	4·53	230	·28	290	3·34	350	4·62
51	·13	111	3·48	171	4·46	231	·25	291	3·43	351	4·56
52	·11	112	3·56	172	4·39	232	·22	292	3·51	352	4·49
53	·09	113	3·64	173	4·32	233	·20	293	3·59	353	4·42
54	·07	114	3·72	174	4·25	234	·18	294	3·66	354	4·34
55	·05	115	3·80	175	4·17	235	·17	295	3·74	355	4·26
56	·04	116	3·87	176	4·10	236	·15	296	3·82	356	4·19
57	·03	117	3·95	177	4·02	237	·15	297	3·89	357	4·11
58	·03	118	4·02	178	3·94	238	·14	298	3·97	358	4·02
59	·03	119	4·09	179	3·86	239	·14	299	4·04	359	3·94
60	·03	120	4·16	180	3·78	240	·14	300	4·11	360	3·86

Moon's max. dec. (1868 May to 1869 May) = 19°·7.

(3) K.—Lunisolar Diurnal and Semidiurnal (Declinational).

$$h=1\cdot167\cos\{\gamma t-142^\circ\cdot87\}+0\cdot239\,\text{ft.}\cos\{2\gamma t-340^\circ\cdot25\}$$

γt	h'	γt	h'	γt	h'	γt	h'	γt	h'	γt	h'
°	ft.	°	ft.	°	ft.	°	ft.	°	ft.	°	ft.
0	0·41	60	1·08	120	2·15	180	2·27	240	0·79	300	0·00
2	0·43	62	1·11	122	2·18	182	2·24	242	0·74	302	0·00
4	0·45	64	1·14	124	2·21	184	2·21	244	0·69	304	0·00
6	0·47	66	1·17	126	2·24	186	2·17	246	0·64	306	0·01
8	0·49	68	1·20	128	2·27	188	2·13	248	0·59	308	0·01
10	0·51	70	1·24	130	2·29	190	2·09	250	0·55	310	0·02
12	0·53	72	1·27	132	2·32	192	2·05	252	0·51	312	0·03
14	0·55	74	1·30	134	2·34	194	2·01	254	0·46	314	0·04
16	0·56	76	1·34	136	2·36	196	1·96	256	0·42	316	0·05
18	0·58	78	1·37	138	2·38	198	1·92	258	0·38	318	0·06
20	0·60	80	1·41	140	2·40	200	1·87	260	0·35	320	0·07
22	0·62	82	1·45	142	2·42	202	1·82	262	0·31	322	0·08
24	0·64	84	1·48	144	2·43	204	1·77	264	0·28	324	0·10
26	0·66	86	1·52	146	2·44	206	1·72	266	0·24	326	0·11
28	0·68	88	1·56	148	2·45	208	1·67	268	0·22	328	0·13
30	0·71	90	1·60	150	2·46	210	1·61	270	0·19	330	0·14
32	0·73	92	1·63	152	2·46	212	1·56	272	0·16	332	0·16
34	0·75	94	1·67	154	2·46	214	1·50	274	0·14	334	0·17
36	0·77	96	1·71	156	2·46	216	1·45	276	0·12	336	0·19
38	0·79	98	1·75	158	2·46	218	1·39	278	0·10	338	0·21
40	0·81	100	1·79	160	2·46	220	1·34	280	0·08	340	0·23
42	0·84	102	1·83	162	2·45	222	1·28	282	0·06	342	0·24
44	0·86	104	1·86	164	2·44	224	1·22	284	0·05	344	0·26
46	0·89	106	1·90	166	2·43	226	1·17	286	0·04	346	0·28
48	0·91	108	1·94	168	2·41	228	1·11	288	0·03	348	0·30
50	0·94	110	1·98	170	2·39	230	1·06	290	0·02	350	0·32
52	0·97	112	2·01	172	2·37	232	1·00	292	0·01	352	0·34
54	0·99	114	2·05	174	2·35	234	0·95	294	0·00	354	0·36
56	1·02	116	2·08	176	2·33	236	0·89	296	0·00	356	0·37
58	1·05	118	2·12	178	2·30	238	0·84	298	0·00	358	0·39
60	1·08	120	2·15	180	2·27	240	0·79	300	0·00	360	0·41

Lunar (Declinational) Diurnal.

(4) O.

$$h=0\cdot569\cos\{(\gamma-2\sigma)t-308^\circ\cdot87\}$$

$(\gamma-2\sigma)t$	h'	$(\gamma-2\sigma)t$	h'	$(\gamma-2\sigma)t$	h'	$(\gamma-2\sigma)t$	h'	$(\gamma-2\sigma)t$	h'	$(\gamma-2\sigma)t$	h'
°	ft.	°	ft.	°	ft.	°	ft.	°	ft.	°	ft.
0	0·93	60	0·36	120	0·01	180	0·21	240	0·77	300	1·13
5	·89	65	·32	125	·00	185	·25	245	·82	305	1·14
10	·84	70	·28	130	·00	190	·29	250	·86	310	1·14
15	·80	75	·23	135	·00	195	·34	255	·91	315	1·14
20	·75	80	·20	140	·01	200	·39	260	·94	320	1·13
25	·71	85	·16	145	·02	205	·43	265	0·98	325	1·12
30	·66	90	·13	150	·04	210	·48	270	1·01	330	1·10
35	·61	95	·10	155	·06	215	·53	275	1·04	335	1·08
40	·56	100	·07	160	·08	220	·58	280	1·07	340	1·06
45	·51	105	·05	165	·11	225	·63	285	1·09	345	1·03
50	·46	110	·03	170	·14	230	·68	290	1·11	350	1·00
55	·41	115	·02	175	·18	235	·73	295	1·12	355	0·96
60	0·36	120	0·01	180	0·21	240	0·77	300	1·13	360	0·93

Solar (Declinational) Diurnal.

(5) P.

$$h=0{\cdot}376\cos\{(\gamma-2\eta)t-316^\circ{\cdot}35\}$$

$(\gamma-2\eta)t$	h'	$(\gamma-2\eta)t$	h'	$(\gamma-2\eta)t$	h'	$(\gamma-2\eta)t$	h'	$(\gamma-2\eta)t$	h'	$(\gamma-2\eta)t$	h'
°	ft.	°	ft.	°	ft.	°	ft.	°	ft.	°	ft.
0	0·65	60	0·29	120	0·02	180	0·10	240	0·47	300	0·74
5	·63	65	·26	125	·01	185	·13	245	·50	305	·74
10	·60	70	·23	130	·00	190	·15	250	·53	310	·75
15	·57	75	·20	135	·00	195	·18	255	·56	315	·75
20	·54	80	·17	140	·00	200	·21	260	·58	320	·75
25	·51	85	·14	145	·00	205	·24	265	·61	325	·75
30	·48	90	·12	150	·01	210	·27	270	·64	330	·74
35	·45	95	·09	155	·02	215	·30	275	·66	335	·73
40	·42	100	·07	160	·03	220	·33	280	·68	340	·72
45	·39	105	·06	165	·05	225	·37	285	·70	345	·71
50	·35	110	·04	170	·06	230	·40	290	·71	350	·69
55	·32	115	·03	175	·08	235	·43	295	·73	355	·67
60	0·29	120	0·02	180	0·10	240	0·47	300	0·74	360	0·65

Lunar Elliptic Semidiurnal.

(6) L.

$$h=0{\cdot}080\cos\{2(\gamma-\tfrac{1}{2}\sigma-\tfrac{1}{2}\varpi)t-108^\circ{\cdot}27\}$$

$(\gamma-\frac{1}{2}\sigma-\frac{1}{2}\varpi)t$		h'	$(\gamma-\frac{1}{2}\sigma-\frac{1}{2}\varpi)t$		h'
°	°	ft.	°	°	ft.
0	180	0·05	90	270	0·11
10	190	·08	100	280	·08
20	200	·11	110	290	·05
30	210	·13	120	300	·03
40	220	·15	130	310	·01
50	230	·16	140	320	·00
60	240	·16	150	330	·00
70	250	·15	160	340	·01
80	260	·13	170	350	·03
90	270	0·11	180	360	0·05

(7) N.

$$h=0{\cdot}622\cos\{2(\gamma-\tfrac{3}{2}\sigma+\tfrac{1}{2}\varpi)t-280^\circ{\cdot}31\}$$

$(\gamma-\frac{3}{2}\sigma+\frac{1}{2}\varpi)t$		h'	$(\gamma-\frac{3}{2}\sigma+\frac{1}{2}\varpi)t$		h'	$(\gamma-\frac{3}{2}\sigma+\frac{1}{2}\varpi)t$		h'	$(\gamma-\frac{3}{2}\sigma+\frac{1}{2}\varpi)t$		h'
°	°	ft.	°	°	ft.	°	°	ft.	°	°	ft.
0	180	0·73	46	226	0·01	90	270	0·51	136	316	1·24
2	182	·69	48	228	·00	92	272	0·55	138	318	1·24
4	184	·65	50	230	·00	94	274	0·60	140	320	1·24
6	186	·60	52	232	·00	96	276	0·64	142	322	1·24
8	188	·56	54	234	·01	98	278	0·68	144	324	1·24
10	190	·52	56	236	·01	100	280	0·73	146	326	1·23
12	192	·48	58	238	·02	102	282	0·77	148	328	1·22
14	194	·43	60	240	·04	104	284	0·81	150	330	1·21
16	196	·39	62	242	·05	106	286	0·85	152	332	1·19
18	198	·35	64	244	·07	108	288	0·89	154	334	1·17
20	200	·31	66	246	·09	110	290	0·93	156	336	1·15
22	202	·28	68	248	·12	112	292	0·97	158	338	1·13
24	204	·24	70	250	·14	114	294	1·00	160	340	1·10
26	206	·21	72	252	·17	116	296	1·04	162	342	1·07
28	208	·18	74	254	·20	118	298	1·07	164	344	1·04
30	210	·15	76	256	·24	120	300	1·10	166	346	1·01
32	212	·12	78	258	·27	122	302	1·12	168	348	0·97
34	214	·10	80	260	·31	124	304	1·15	170	350	0·94
36	216	·08	82	262	·35	126	306	1·17	172	352	0·90
38	218	·06	84	264	·39	128	308	1·19	174	354	0·86
40	220	·04	86	266	·43	130	310	1·21	176	356	0·82
42	222	·03	88	268	·47	132	312	1·22	178	358	0·77
44	224	·01	90	270	0·51	134	314	1·23	180	360	0·73
46	226	0·01				136	316	1·24			

Lunisolar Semidiurnal {(*Evection*) and (*Variation*)}.

(8) λ.

$$h=0{\cdot}061\cos\left\{2(\gamma-\tfrac{1}{2}\sigma+\tfrac{1}{2}\varpi-\eta)t-156^\circ{\cdot}46\right\}$$

$(\gamma-\frac{1}{2}\sigma+\frac{1}{2}\varpi-\eta)t$		h'
°	°	ft.
0	180	0·01
10	190	·02
20	200	·03
30	210	·05
40	220	·08
50	230	·10
60	240	·11
70	250	·12
80	260	·12
90	270	·12
100	280	·11
110	290	·09
120	300	·07
130	310	·05
140	320	·03
150	330	·01
160	340	·00
170	350	·00
180	360	0·01

(10) μ.

$$h=0{\cdot}070\cos\left\{2(\gamma-2\sigma+\eta)t-269^\circ{\cdot}99\right\}$$

$(\gamma-2\sigma+\eta)t$		h'
°	°	ft.
0	180	0·07
10	190	·05
20	200	·03
30	210	·01
40	220	·00
50	230	·00
60	240	·01
70	250	·03
80	260	·05
90	270	·07
100	280	·09
110	290	·12
120	300	·13
130	310	·14
140	320	·14
150	330	·13
160	340	·12
170	350	·09
180	360	0·07

(9) ν.

$$h=0{\cdot}196\cos\left\{2(\gamma-\tfrac{3}{2}\sigma-\tfrac{1}{2}\varpi+\eta)t-255^\circ{\cdot}63\right\}$$

$(\gamma-\frac{3}{2}\sigma-\frac{1}{2}\varpi+\eta)t$		h'
°	°	ft.
0	180	0·15
5	185	·12
10	190	·09
15	195	·06
20	200	·04
25	205	·02
30	210	·01
35	215	·00
40	220	·00
45	225	·01
50	230	·02
55	235	·03
60	240	·06
65	245	·08
70	250	·11
75	255	·14
80	260	·18
85	265	·21
90	270	·25
95	275	·28
100	280	·31
105	285	·33
110	290	·36
115	295	·37
120	300	·39
125	305	·39
130	310	·39
135	315	·39
140	320	·38
145	325	·36
150	330	·34
155	335	·31
160	340	·28
165	345	·25
170	350	·22
175	355	·18
180	360	0·15

Lunar Elliptic Diurnal.

(11) J.

$$h=0{\cdot}080\cos\left\{(\gamma+\sigma-\varpi)t-178^\circ{\cdot}58\right\}$$

$(\gamma+\sigma-\varpi)t$	h'	$(\gamma+\sigma-\varpi)t$	h'
°	ft.	°	ft.
0	0·00	180	0·16
20	·01	200	·15
40	·02	220	·14
60	·04	240	·12
80	·07	260	·09
100	·10	280	·06
120	·12	300	·04
140	·14	320	·02
160	·16	340	·00
180	0·16	360	0·00

(12) Q.

$$h=0{\cdot}111\cos\left\{(\gamma-3\sigma+\varpi)t-308^\circ{\cdot}23\right\}$$

$(\gamma-3\sigma+\varpi)t$	h'	$(\gamma-3\sigma+\varpi)t$	h'
°	ft.	°	ft.
0	0·18	180	0·04
20	·15	200	·08
40	·11	220	·11
60	·07	240	·15
80	·04	260	·18
100	·01	280	·21
120	·00	300	·22
140	·00	320	·22
160	·02	340	·21
180	0·04	360	0·18

Solar Elliptic Semidiurnal.

(13) **R.**

$$h=0{\cdot}035\cos\left\{2(\gamma-\tfrac{1}{2}\eta)t-12^\circ{\cdot}04\right\}$$

$(\gamma-\frac{1}{2}\eta)t$		h'	$(\gamma-\frac{1}{2}\eta)t$		h'
°	°	ft.	°	°	ft.
0	180	0·07	90	270	0·00
10	190	·07	100	280	·00
20	200	·07	110	290	·00
30	210	·06	120	300	·01
40	220	·05	130	310	·02
50	230	·04	140	320	·03
60	240	·02	150	330	·05
70	250	·01	160	340	·06
80	260	·01	170	350	·06
90	270	0·00	180	360	0·07

(14) **T.**

$$h=0{\cdot}111\cos\left\{2(\gamma-\tfrac{3}{2}\eta)t-38^\circ{\cdot}96\right\}$$

$(\gamma-\frac{3}{2}\eta)t$		h'	$(\gamma-\frac{3}{2}\eta)t$		h'
°	°	ft.	°	°	ft.
0	180	0·20	90	270	0·02
10	190	·22	100	280	·01
20	200	·22	110	290	·00
30	210	·22	120	300	·01
40	220	·20	130	310	·03
50	230	·16	140	320	·06
60	240	·13	150	330	·09
70	250	·09	160	340	·13
80	260	·05	170	350	·17
90	270	0·02	180	360	0·20

Lunisolar Quarter-diurnal (Helmholtz).

(15) **MS.**

$$h=0{\cdot}017\cos\left\{4(\gamma-\tfrac{1}{2}\sigma-\tfrac{1}{2}\eta)t-216^\circ{\cdot}79\right\}$$

$(\gamma-\frac{1}{2}\sigma-\frac{1}{2}\eta)t$		h'	$(\gamma-\frac{1}{2}\sigma-\frac{1}{2}\eta)t$	
°	°	ft.	°	°
0	90	0·00	180	270
10	100	·00	190	280
20	110	·00	200	290
30	120	·01	210	300
40	130	·02	220	310
50	140	·03	230	320
60	150	·03	240	330
70	160	·02	250	340
80	170	·01	260	350
90	180	0·00	270	360

$\Sigma R-0{\cdot}290$ ft.* $=7{\cdot}157$ ft. $A_0=7{\cdot}149$ ft. $A_0-\Sigma R-0{\cdot}290$ ft. $=-0{\cdot}008$ ft. $=-0{\cdot}01$ ft.

The following example will illustrate the manner of computation at present employed, in which the whole of the evaluated tide-components are taken into account, excepting those of long period, the values of which, for Kurrachee for successive years, have not agreed well together; they have, therefore, been omitted in the computation.

Find the height of the tide at Kurrachee for every hour of the day for 1868, November 2, commencing at 0^h astronomical reckoning. For 1868, November 2, 0^h Kurrachee mean time,

Sidereal time	=	$\gamma=221^\circ{\cdot}86$,
Sun's mean longitude	=	$\eta=221{\cdot}86$,
Moon's mean longitude	=	$\sigma=67{\cdot}42$,
Moon's mean anomaly	=	$\sigma-\varpi=281{\cdot}00$,

from which the whole of the arguments can be obtained.

The values of the arguments for the succeeding hours are obtained from the arguments for noon by successive additions of their respective hourly in-

* In the lunisolar declinational diurnal and semidiurnal tide the sum of R_1 and R_2 less 0·29 ft. was applied.

crements (p. 361), and these additions may be continued for any period whatever. These are most readily obtained by the use of the arithmometer of Thomas (de Colmar).

The residual differences, on this and the following page, are for the most part negative, and indicate that the mean height of the water on the day in question was above the mean height of the water for the whole year. On trial it will be found that the excess equals 0·15 of a foot, a quantity such that, if applied to the residual differences, will make them all very small.

Kurrachee, 1868, November 2.

No. of Table.		Value of argument at 0^h.	0^h.	1^h.	2^h.	3^h.	4^h.	5^h.
		°	ft.	ft.	ft.	ft.	ft.	ft.
1	$\gamma-\eta$	0·00	1·67	1·30	·83	·39	·11	·07
2	$\gamma-\sigma$	154·44	5·22	4·60	3·49	2·25	1·15	·38
3	γ	221·86	1·29	·87	·51	·23	·06	·00
4	$\gamma-2\sigma$	87 02	·15	·07	·02	·00	·02	·07
5	$\gamma-2\eta$	138·15	·00	·02	·06	·12	·20	·29
6	$\gamma-\frac{1}{2}\sigma-\frac{1}{2}\varpi$	294·94	·04	·01	·00	·01	·03	·08
7	$\gamma-\frac{3}{2}\sigma+\frac{1}{2}\varpi$	13·94	·43	·18	·02	·01	·15	·41
8	$\gamma-\frac{1}{2}\sigma+\frac{1}{2}\varpi-\eta$	219·50	·08	·11	·12	·12	·11	·09
9	$\gamma-\frac{3}{2}\sigma-\frac{1}{2}\varpi+\eta$	89·37	·24	·32	·38	·39	·36	·28
10	$\gamma-2\sigma+\eta$	308·88	·14	·14	·12	·09	·06	·03
11	$\gamma+\sigma-\varpi$	142·86	·14	·16	·16	·16	·15	·14
12	$\gamma-3\sigma+\varpi$	166·02	·03	·04	·06	.09	·11	·14
13	$\gamma-\frac{1}{2}\eta$	110·93	·00	·01	·03	·05	·06	·07
14	$\gamma-\frac{3}{2}\eta$	249·07	·09	·04	·01	·00	·03	·07
15	$\gamma-\frac{1}{2}\sigma-\frac{1}{2}\eta$	77·22	·01	·00	·00	·01	·03	·03
	$A_0-\Sigma R-0·290$ ft.	......	− ·01	− ·01	− ·01	− ·01	− ·01	− ·01
	Calculated height	=C=	9·52	7·86	5·80	3·91	2·62	2·14
	Height from diagram	=O=	9·7	7·9	5·8	4·0	2·7	2·3
		C−O=	− ·18	− ·04	·00	− ·09	− ·08	− ·16

No. of Table.	6^h.	7^h.	8^h.	9^h.	10^h.	11^h.	12^h.	13^h.	14^h.
	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.
1	·27	·67	1·16	1·62	1·93	2·00	1·82	1·43	·95
2	·14	·62	1·66	2·91	4·06	4·94	5·33	5·03	4·08
3	·03	·12	·24	·38	·53	·67	·84	1·04	1·23
4	·15	·25	·38	·50	·65	·78	·90	1·00	1·08
5	·39	·49	·57	·65	·71	·74	·75	·74	·71
6	·12	·15	·16	·15	·12	·09	·05	·01	·00
7	·70	1·00	1·19	1·24	1·15	·92	·63	·33	·11
8	·05	·02	·00	·00	·02	·03	·07	·10	·12
9	·19	·10	·02	·00	·02	·09	·19	·28	·36
10	·01	·00	·01	·04	·07	·10	·13	·14	·13
11	·12	·10	·08	·06	·04	·03	·01	·00	·00
12	·16	·18	·20	·21	·22	·22	·22	·21	·19
13	·07	·05	·04	·02	·01	·00	·00	·02	·03
14	·13	·18	·22	·22	·20	·15	·09	·04	·01
15	·01	·00	·00	·01	·02	·03	·02	·00	·00
	− ·01	− ·01	− ·01	− ·01	− ·01	− ·01	− ·01	− ·01	− ·01
C=	2·53	3·92	5·92	8·00	9·74	10·78	11·04	10·36	9·04
O=	2·7	4·2	6·0	8·0	9·8	10·8	11·0	10·4	9·1
C−O=	− ·17	− ·28	− ·08	·00	− ·06	− ·02	+ ·04	− ·04	− ·06

No. of Table.	15h. ft.	16h. ft.	17h. ft.	18h. ft.	19h. ft.	20h. ft.	21h. ft.	22h. ft.	23h. ft.
1	·49	·18	·09	·26	·62	1·08	1·52	1·80	1·86
2	2·81	1·55	·56	·05	·25	1·15	2·42	3·66	4·65
3	1·54	1·84	2·11	2·33	2·45	2·45	2·32	2·03	1·67
4	1·12	1·14	1·12	1·07	·98	·88	·75	·62	·47
5	·65	·57	·48	·38	·28	·20	·12	·06	·02
6	·01	·03	·07	·11	·14	·16	·15	·13	·09
7	·00	·05	·24	·51	·81	1·07	1·23	1·22	1·09
8	·12	·11	·09	·06	·03	·01	·00	·01	·03
9	·39	·38	·33	·23	·14	·06	·01	·01	·04
10	·12	·08	·06	·03	·01	·00	·01	·04	·07
11	·01	·02	·03	·05	·07	·09	·11	·13	·14
12	·17	·15	·12	·10	·07	·05	·03	·01	·00
13	·06	·06	·07	·07	·05	·04	·02	·01	·00
14	·00	·03	·07	·12	·18	·22	·22	·20	·15
15	·01	·02	·03	·02	·00	·00	·01	·02	·03
	− ·01	− ·01	− ·01	− ·01	− ·01	− ·01	− ·01	− ·01	− ·01
C =	7·49	6·20	5·46	5·38	6·07	7·45	8·91	9·94	10·30
O =	7·7	6·4	5·6	5·5	6·4	7·6	9·1	10·1	10·5
C−O =	− ·21	− ·20	− ·14	− ·12	− ·33	− ·15	− ·19	− ·16	− ·20

On the Brighton Waterworks. By Edward Easton, *C.E., F.G.S.*

[A communication ordered by the General Committee to be printed *in extenso*.]

Obviously the first question an engineer asks when called upon to design works for the supply of water to a large population is, From what source can water of pure quality, and practically inexhaustible in quantity, be obtained?

On taking a survey of the country surrounding Brighton, its most striking feature, probably, is the entire absence of all streams, and, indeed, of all signs of the existence of the water the engineer is in search of. Standing on one of the highest Downs above the town, and looking down upon the slopes and valleys below him, the aspect of the country, as far as the eye can reach, appears for his purpose as unpromising as the Great Desert of Sahara. But just as in that vast arid region there exists beneath the burning sands the element which, by the application of scientific knowledge and mechanical skill, will change the useless desert into a fruitful plain, so lie concealed within the apparently dry material of the chalk stratum streams of excellent water which, though not presenting to the eye the beauty so admirably delineated by our great English painter, are none the less unfailingly "flowing to the sea."

Let us imagine our observer overtaken by one of those sudden and violent storms of rain which were so frequent during the earlier part of this year. He is looking down into a basin naturally formed in the chalk of perhaps two square miles in extent. The middle or bottom of the basin is at least 60 feet below the lowest part of its sides. In an hour there falls sufficient rain to fill the lower and smaller area of the basin to the depth of several feet. No such result, however, follows the downpour; the rain disappears as quickly as it falls, and in less than an hour the surface of the ground is as dry as it was before the storm. The water has all been received into the absorbing ground, and is finding its way through the pores of the chalk down into subterranean streams and so into the sea. That this is the case can be ascertained by walking down to the shore at low water, and tasting any of the numerous

rills flowing from the higher parts of the beach through the shingle. But these streams are rills and not torrents, as they might be expected to be after the enormous downfall of rain; and there is clearly some storage reservoir intervening which has prevented its immediate discharge. This is the chalk itself, which acts as a sponge and stores up the water until saturation takes place, and it is obliged, as it were reluctantly, to give up what it has lost the power of retaining.

The problem now to be solved by the engineer is, How can this water thus running wastefully into the sea be made use of for the purpose in view? A description of the waterworks constructed for the supply of this place will go far to answer the question. Brighton has always been supplied with water from wells sunk in the chalk stratum. In a description of the town, written in the year 1761, by Dr. Relhan, a physician who succeeded the well-known Dr. Richard Russell, it is stated:—"The town is supplied from a variety of wells. The water most esteemed by the inhabitants is drawn from a well in North Street, and that preferred by the Company is obtained at the Castle Tavern. These waters answer every domestic purpose of life extremely well; and as the qualities of springs of any place have been from the time of Hippocrates to this day looked upon as a mark of those of the air, the sweetness and goodness of spring-water here may with propriety be esteemed a corroborating proof of the healthfulness of the air of this town." Such wells as these supplied the inhabitants until about the year 1830, when a Company was formed by a few public-spirited men, the late Mr. Peter Cazalet and Dr. Taylor, who, I believe, is still living, being among its most active members, and a system of waterworks was established. A well was sunk near the Lewes Road, about $1\frac{1}{4}$ mile in a direct line from the sea-shore; and the water obtained was pumped by steam into a reservoir 220 feet above the sea, and thence distributed through pipes over the town. It was soon found that a single well would not give sufficient for the rapidly increasing population, and that the engines drew the water faster than the springs would give it; and tunnels or adits were driven in the form of a cross for the double purpose of obtaining more water and of making a storage from which the pumps might draw. A boring was also made into the chalk below to a great depth, but, for reasons which will be presently apparent, without any beneficial result. In the year 1852, in consequence of the great complaints of the scarcity of water, a new Company was formed, and an Act of Parliament obtained authorizing the construction of more extensive works. In the following year another Act was passed, by which the old Company sold their works to the new comers, and under the powers of which the works as they now exist were commenced.

It was soon found that the wells and tunnels were totally inadequate for the supply even of the services then laid on, whose number was scarcely half that of the total number of houses; and the new Company, acting under the advice of the late Mr. Easton, their engineer, immediately on coming into possession of the works, commenced a new series of tunnels on a principle successfully adopted by Mr. Easton in the year 1834 when constructing works for the supply of the town of Ramsgate, a principle, as far as the writer is aware, which had never been before proposed. Ramsgate, as is well known, is built on the Chalk formation of the Isle of Thanet. Mr. Easton, in making his survey of the locality, observed that all along the sea-coast there issued at the base of the chalk cliffs numerous streams of fresh water running across the beach into the sea at low water; and he concluded that these streams came from cracks or fissures in the chalk, and that if tunnels were driven

in a direction parallel to the sea, and at about the level of low water, these fissures would be cut across and the water intercepted and stored in the tunnels. His conclusions were amply verified. Ramsgate has been supplied since the year 1836 from wells and tunnels made on this principle.

The town of Brighton is very similarly situated. For at least 6 miles to the north, as many to the west, and nearly 8 miles to the eastward, there is a succession of Chalk Downs untraversed by any river or stream. The geological formation is that of the Upper Chalk with flints. Throughout the whole of this district (with a few exceptions of no importance) there is no system of agricultural drainage: none is required. The whole of the rainfall, except that absorbed by the vegetation or given off by evaporation, percolates at once into the chalk, and has its chief outlet in the sea as before described,—its chief outlet, because all round the base of the great escarpment at the northern boundary of the Chalk Downs there flow out springs more or less copious, which are formed by the overflow of the great chalk reservoir when saturation has taken place. Such springs, for instance, are those at Poynings, at Plumpton, and at Clayton. They find their way into the sea by the river Adur at Shoreham on the west, and the Ouse at Newhaven on the east. The volume of these springs, however, is but a very small percentage of the total quantity of rainfall, the main body of which is absorbed by the chalk, and by its means travels to the sea. But although the chalk is as absorbent as a sponge, it is equally unready to give up its contents; and, consequently, were it not for some outlet more free and open than those afforded by its own pores it would necessarily overflow, and the ordinary phenomena of surface-streams would result. These freer outlets are provided in the shape of clefts or fissures extending almost from the surface downwards to a very great depth, which have been formed in all probability, in the first instance, and continually kept open, by the action of the water through a vast series of years. Where the stratification of the chalk has not been disturbed by local upheavals and depressions, these fissures are almost invariably at right angles to the coast-line: each is entirely independent of its neighbour, and forms in itself a small rivulet, which takes its origin from the supersaturation of the chalk, and flows down collecting water as it goes, and finally discharges itself into the sea. The sides of these fissures are generally of the colour of mahogany, caused by the infiltration of small particles of the upper clays, and are polished by the continuous friction of the water. The fissures vary in size, but are seldom more than a few inches in width, and generally not more than $\frac{3}{4}$ of an inch; there is therefore considerable resistance to the passage of the water, and consequently as the body of the chalk gets full the pressure keeps on increasing, as shown by the varying level of the water in the wells. The diagram on the wall shows the quantity of rainfall of each month for the 10 years 1862 to 1872, and also the fluctuations of the level of the water in the wells on the Lewes Road. This latter varies, as will be seen, from as low as 5 feet in depth in the autumn of the year 1864 to as much as 88 feet in depth in the spring of the year 1866. Speaking generally, the maximum quantity of water in the chalk is in March each year, and the minimum in October to December; and the curve formed by the depths of the water follows that of the quantity of rain at an interval of four months, the highest part of the one curve being nearly coincident with the lowest of the other. It follows that the chalk is acting exactly as a storage reservoir, and is receiving the surplus rainfall of the months of October, November, December, and January (when, in consequence of the low temperature and the comparative sluggishness of vege-

tation, nearly all that falls goes down to feed the springs), and giving out in the summer the quantity so stored. At intervals the reservoir becomes full to overflowing, and then is seen the same phenomenon which is known in the Caterham valley as the rise of the Bourne, and the surplus water bursts out. This happened in 1852 in the Preston valley, when there was a considerable stream running down the London Road, and in 1866 in the Lewes-Road valley, when the basements of the houses were flooded with the spring-water. A similar bourne or overflow occurs periodically after wet seasons and runs down through the town of Lewes.

The course of the rainfall, in its passage to the sea, is still further illustrated by four sections, which show the depth of water in a number of wells, soundings of which were all taken at the same time. Sections A, B, C give the soundings of wells situated in lines running northward from the sea, and as nearly as possible at right angles to the coast-line. Section D gives the depths of several wells dug at about the same distance from the sea, along a line running from E. to W. It will be seen that there is a uniform slope in the water-level of the chalk in the former sections, whilst the water-level in the latter is almost the same throughout. The furthest of the wells in sections A, B, C is not more than 2 miles from the sea; but levels taken to a well lately sunk at the foot of the chalk escarpment, about 1 mile east of the end of Clayton Tunnel, show that the water there stands at the height of about 250 feet above low water, and that the line of the water in section B B would, if produced, very nearly cut that of the well just mentioned, which is about 6 miles in a direct line from the coast.

Up to the year 1865 the whole of the town was supplied from the Lewes-Road Works; but in that year it was determined, in consequence of the great demand for water, to erect another pumping-station on the west side. Accordingly a well was sunk at Goldstone Bottom, and tunnels driven to the extent of about a quarter of a mile across the valley, parallel to the sea. Goldstone Bottom is a naturally formed basin in the chalk, the lowest side of which, nearest the sea, is more than 60 feet higher than the middle or bottom of the basin. The water is obtained, as at Lewes Road, from fissures running generally at right angles to the coast-line; but they are of much larger size and at far greater distances from each other: whereas at the Lewes-Road Works it is rare that 30 feet of tunnels were driven without finding a fissure, and the produce of the largest was not more than 100 to 150 gallons per minute, at Goldstone nearly 160 feet were traversed without any result, and then an enormous fissure was pierced, which delivered at once quite 1000 gallons per minute; and the same interval was found between this and the next fissure, which was of a capacity very nearly as great. In consequence of the great size of these there is a much freer vent to the sea, and the water stands relatively to the Lewes-Road valley at a much lower level, being generally not more than 25 feet above low water. The fluctuations also of the water are not great, the difference of the quantity of water being felt rather by the impossibility of the pumps lowering its level than in its rising higher.

The total length of the tunnels at Lewes-Road Works is 2400 feet, and at Goldstone 1300 feet.

So much for the sources of the water. A short description of the pumping and distributing works must now be given.

The district supplied by the waterworks comprises not only the parish of Brighton, but the neighbouring parishes of Hove and Preston. The number of houses supplied, which in 1854 did not much exceed 7000 when the new Company purchased the works, had risen on the 1st of August last, when

they were transferred to the Corporation, to 18,000. The number of inhabitants at the last census in the whole district was 103,000, to which must be added, in the fashionable season, from 30,000 to 50,000 visitors.

The area of the district is considerable, being, as nearly as possible, four miles in length from east to west, and about two miles from north to south. The ground is very undulating, varying in level from 30 feet above the sea to as much as 450 feet. In order to avoid lifting the water higher than is necessary and at the same time to prevent undue pressure on the service-pipes and fittings, the plan has been adopted of dividing the district into four zones or services, each fed by its own reservoir or reservoirs, with its own system of main pipes. The highest zone (at present but little built upon) is commanded by a reservoir containing 500,000 gallons, built at a height of 450 feet above the sea, on the Down, about half a mile north of the Grand Stand of the racecourse.

The next zone is called the high service. It is fed from two reservoirs—one at Park Road on the east, containing 500,000 gallons, and the other on the Dyke Road, on the west side, containing 600,000 gallons; both of these are at the same level of 300 feet above the sea; they are connected by distributing mains, and give a supply to about two ninths of the town.

The third zone is the middle service, supplying about three ninths of the whole number of inhabitants. It draws its supply from a reservoir near Brighton Park, containing 2,000,000 gallons, the water-level being 220 feet above the sea.

The remaining or low service supplies about four ninths of the whole, and is fed from two reservoirs—one above the Lewes-Road Works containing 1,000,000 gallons, and the other at Goldstone Bottom 600,000 gallons. These are at the level of 150 feet above the sea.

The high and low services, as already mentioned, have reservoirs at the same level on both sides of the town, with main pipes connecting them together. Those on the west side were constructed in 1863 and 1865, when the western districts increased, and it was found difficult, in consequence of the great length of the supply main, to give proper pressure at the extremities of the districts. The effect of putting them at the same level is that during the night, when little water is drawn by the consumers, the water pumped into the reservoirs on the one side passes through the mains to those on the other, and becomes available in the morning for serving the houses, the supply being drawn at an equal pressure from both reservoirs simultaneously, the length of the supply mains being thus practically reduced by one half.

All the zones are connected together, and stopcocks are arranged so that, in case of fire, the water from the upper can be let down into the lower service mains, self-acting valves being fixed on the outlet of each reservoir to prevent the passage into it of the water from the reservoir above.

The total quantity of water pumped daily varies from $2\frac{1}{2}$ millions in the winter to 3 millions in the summer months. The amount per head per diem is from 17 to 20 gallons, including street watering and large consumers.

The water is supplied both on the intermittent and constant system. When the new Company obtained their first Act, the intention was to furnish a supply only on the constant service; but on buying the old works they found themselves unable to keep up the supply in consequence of the enormous waste of water caused by the old fittings in the houses; and as they could not obtain any relief in the shape of delay, but were obliged at once to give constant service, the Directors determined to lay a duplicate set of service-pipes in every street, so that when called upon they could give either form

of supply to every house. This was done, and Brighton is now in the position of being able to give constant service to one house, and intermittent to the house next door in the same street. The number of constant-service customers now amounts to about 5000.

The pumping-power at the two stations of Lewes Road and Goldstone Bottom is as follows:—

At Lewes Road there are two engines of the nominal power of 100 horses and 150 horses respectively, the one capable of raising out of the wells 130,000 gallons per hour, and the other 150,000 gallons per hour: the boiler-power at this station is equal to about 350 horses.

At Goldstone Bottom there is one engine of the nominal power of 150 horses, raising 150,000 gallons per hour, and supplied with steam from three boilers of the collective power of 240 horses nominal.

The wells and tunnels at each station are capable of affording at the dryest season the maximum daily supply of 3 millions of gallons.

The engines are all on Woolf's principle, high and low pressure condensing beam-engines, the smaller cylinder being 28 inches diameter, and the larger 46 inches, the stroke of the latter being 8 feet. They are erected directly over the wells, which are of an elliptical shape, 12 feet across the longer and 8 feet across the shorter axis. The centre of the beam is immediately over the centre of the well. On each side of the centre, at the bottom of the wells, is fixed a single-acting pump $29\frac{1}{2}$ inches diameter, 3-feet stroke: these pumps raise the water into the low-service reservoirs above described. Also under the beam, at the crank end, is fixed a bucket and plunger double-acting pump, drawing its water from the delivery of the deep-well pumps, and forcing it to the high or middle service at pleasure: this pump is 2 feet diameter, 4-feet stroke. At the Lewes-Road Works there are also two sets of three throw-pumps capable of raising 400 gallons per minute each, and at Goldstone a horizontal double-acting pump, equal to 600 gallons per minute, for the middle service. The highest service of all is fed only from the Lewes-Road Works, there being a separate double-acting pump under each engine at that station exclusively for its supply.

Thus each of the engines at the same time can pump into all the three zones or services, and keep up the supply without any manipulation of cocks and valves, and without altering the working pressure on the engine.

The reservoirs are all constructed in the chalk of brickwork, without any puddle; they are lined with two courses of tiles in pure cement, and are arched over with $4\frac{1}{2}$ arches in cement, and covered 12 inches to 18 inches deep with soil. This arrangement keeps the water perfectly pure and cool, and prevents the vegetation which grows so quickly in chalk water when exposed to the action of light and air. From the time of its leaving the tunnels at the bottom of the wells to its being delivered into the houses it is never exposed to any contaminating influence, and is thus used by the inhabitants, especially those on the constant service, in a perfectly pure state.

It will be seen from the foregoing that—

1. There are two distinct sources of supply, each sufficient at the dryest season to give the maximum quantity required, and capable of still further development as the town increases.

2. There are three sets of pumping-apparatus, each equal, on an emergency, to the delivery of this maximum quantity in 24 hours.

3. There is besides a reservoir storage of two days' supply, on the average, for each zone or service.

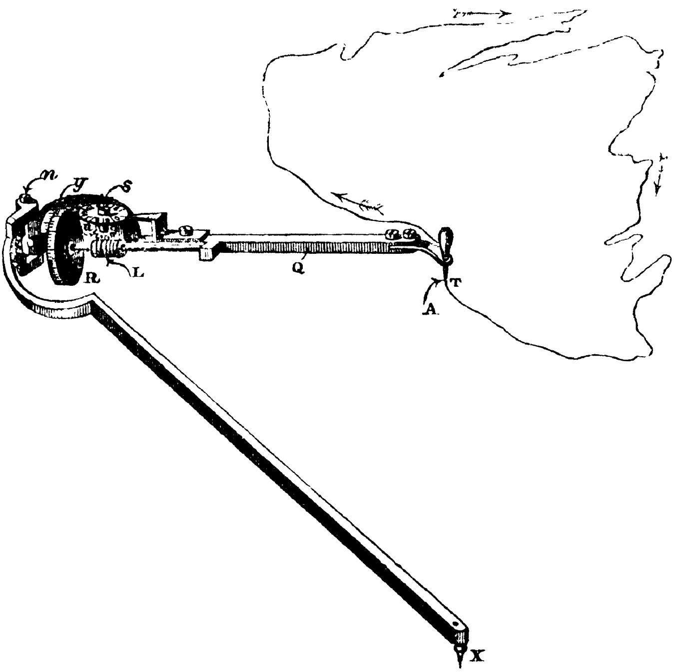
On Amsler's Planimeter. *By* F. J. BRAMWELL, *C.E.*

[A communication ordered by the General Committee to be printed *in extenso*.]

THIS machine for measuring the area of any figure, however irregular, by the mere passage of a tracer round about its perimeter, has now been in use for some years; but, so far as the writer is aware, no easily intelligible statement of its principles of action has ever been made public.

Although no doubt the mere construction of the planimeter is now generally known, it may enable the explanation which is about to be offered to be more easily followed if a sketch of the actual machine, as at work upon a map, be given here (see fig. 1).

Fig. 1.



Assume the planimeter to be anchored by its point X, and the tracer T to be at some place, say A, on the circumference of the area to be ascertained; and assume the indices on the first wheel R and on the second wheel S to be at zero, and that then the tracer T be carried along the perimeter of the area in the direction of the arrows (with the sun), the indices will give a reading up to four figures, which will represent square inches, to two places of whole numbers and to two places of decimals.

This movement of the indices is effected by the wheel R, the edge of which bears upon the paper, so that as the tracer T is made to go round about the figure to be measured, the wheel R, from its contact with the paper, receives rotary motion, and by means of the worm-pinion L and worm-wheel *n*, communicates a diminished motion (1-10th) to the horizontal wheel *s*.

The circumference of the wheel R is "divided," and it works against a vernier at y; the horizontal wheel s gives "tens" in square inches, the larger divisions on the travelling wheel R "units," the smaller divisions on that wheel "tenths," and the vernier "hundredths" of square inches. All that has to be done for ascertaining an area is to read the indices after the machine is anchored and the tracer is put to the starting-point; but before it is started, to book the reading, to re-read after the circuit of the figure has been made, and then to deduct the first reading from the second; the remainder gives the area (in square inches and decimals) of the particular figure.

The foregoing being, briefly stated, the construction, the manner of using, and the result of that using of the planimeter, it now remains to endeavour to show, as intelligibly as possible, why it is that such an implement, by merely following the boundary of a figure, should give with absolute accuracy the area of that figure.

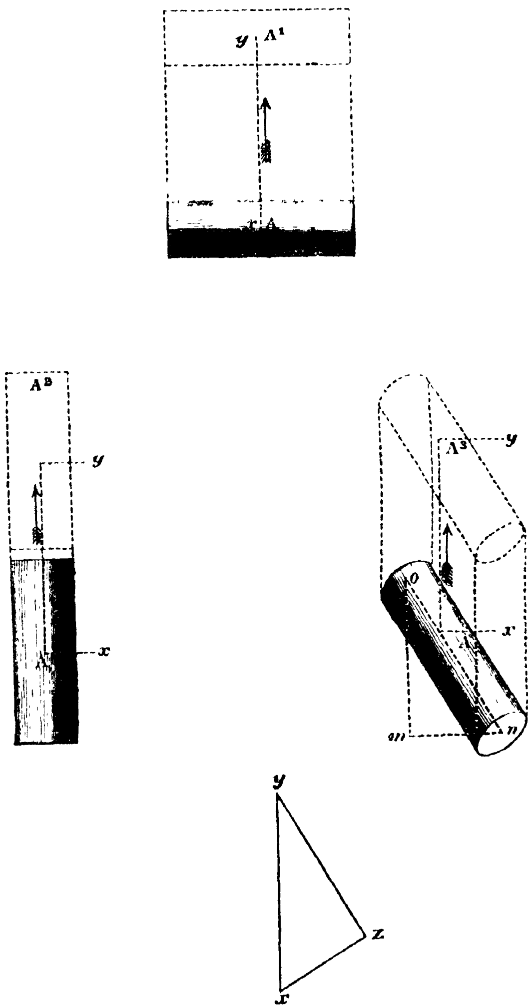
Such a proposition at first sight appears to involve an impossibility. One is in the habit of saying, and of most truly saying, that there is no fixed relation between perimeter and area; and of saying, moreover (and also truly), that not only is this the fact when areas of great irregularity are dealt with, but, as regards direct proportion, it is also the fact when the most regular figures (figures in all respects the same, except in their actual size) are under consideration; for it is as true that the circumferences of perfectly regular figures like circles bear no more fixed direct proportion to the areas of those circles, unless the exact size be known, as it is true that the coast-line of Norway, indented with its deep fjords, bears no more relation to the area of that romantic country than the perimeter of a prosaic rectangular portion of the United States bears to the square miles of prairie contained within it. These things being so, it does, as has already been said, seem at first sight absurd to endeavour to obtain from the traverse of a perimeter, be that perimeter the most regular imaginable (and if possible still more absurd when that perimeter may be the most irregular imaginable), the correct area contained within it, not merely in terms of the perimeter, but in a definite standard measurement, such as square inches.

As a preliminary to the investigation of the action of an elementary planimeter, let the results of the moving of a plain cylinder in contact with a flat surface, and under certain varying conditions, be considered.

Assume a cylinder, as A in fig. 2, and that it is intended to move that cylinder parallel with itself in the direction shown by the arrow, over the length $x\,y$. The cylinder may be (1st) at right angles to the direction in which it is to be traversed, as in A A^1. If under these circumstances the cylinder be moved from x to y and brought into the position as dotted at A^1, the motion will be entirely one of rolling, without any sliding whatever; and if there were upon the surface a trace ($x\,y$) of ink capable of making a mark upon the cylinder, there would be found circumferentially upon it, when it had reached the new position, a line, the length of which would be equal to $x\,y$. (2nd) The cylinder may be placed with its axis parallel to the direction of motion, as at A A^2; then no rolling action would take place, but the cylinder would simply slide endways upon the surface. The cylinder would, however, still bear upon it the trace $x\,y$, equal in length to the distance it had moved through, but that trace would be obviously a mere straight line in the direction of the axis of the cylinder. (3rd) The cylinder may be in a position intermediate between that of A A^1 and A A^2; that is to say, may be neither at right angles to the line of motion, as in A A^1, nor parallel with the line of motion, as in A A^2, but at an angle therewith, as in A A^3. In this instance,

on the cylinder being caused to traverse from x to y, the motion will be one compounded of rolling and of sliding; the trace will still be made on the cylinder; the length of that trace will be, as before, the length $x\,y$, but the trace will now be a spiral, which may be developed into the triangle $x\,y\,z$, and the base $x\,z$ will bear such a relation to the hypotenuse $x\,y$ as the base $m\,n$ of the triangle $m\,n\,o$ bears to the hypotenuse $n\,o$. But it has been

Fig. 2.

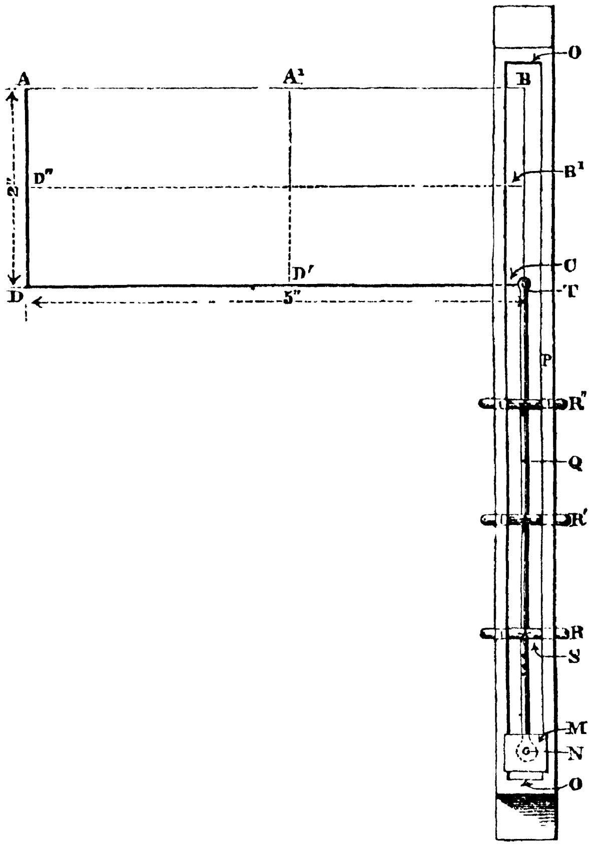


said that in the journey from x to y the cylinder will have had a motion compounded of sliding and of rolling; the extent of the rolling will clearly bear that proportion to the total traverse $x\,y$ that the base $m\,n$ bears to the hypotenuse $n\,o$; and this proportion may obviously be any thing between the

absolute equality which would exist in A A^1 down to the absence of all rolling motion which would obtain in the case of A A^2.

These preliminaries being stated, let it be inquired how they apply to the action of the planimeter. For this purpose it will be well to refer to the sketch, fig. 3. This sketch shows an imaginary elementary planimeter, used

Fig. 3.



to ascertain the area of the rectangle A B C D, the length of each of its sides A B, C D being 5 inches, and the length of each of its ends D A, C B being 2 inches, so that its area is 10 inches. Let M be a block carrying the pivot N and capable of sliding in the straight groove O O in the bridge P, pinned down over the paper, and let Q be a rod pivoted at N, and say, for the sake of illustration, 5 inches long from the pivot N to the tracer T at its opposite end; and let it have on it, say at R, a wheel R, having a circumference of exactly 2 inches; and also, for the sake of a second illustration, let there be similar wheels as R′, R″ free to revolve on the rod Q, at distances greater than the distance of the wheel R from the pivot N; and let there be to one of the wheels, say R, a pointer S, to enable the graduated divisions on the circumference of R to be read off.

Now let it be assumed that the tracer T is moved from C to D; the result will be that during the motion the block M will gradually pass along the groove O until the time when the tracer T has reached D; and then, as the length of the rod Q is exactly 5 inches, equal to the length of the side C D (5 inches), the block M must have passed along the groove O until the centre N in that block is immediately over the point C, and the centre line of Q is coincident with the line C D. If, now, the tracer T be moved along the 2 inches from D to A, the block M must move parallel with it, and the axis Q of the wheels R, R′, R″ will therefore be at right angles to the line of motion, and the wheels themselves will, like the cylinder A in A A[1] of fig. 2, have a rolling motion, and a rolling motion only; and thus by the time the tracer T has reached the point A, these wheels will each have made an entire revolution. If, now, the circumference of R or R′, R″ has been divided into ten equal parts, and if on setting out from D pains had been taken to put the wheel R with its zero mark to the pointer S, it would be found, on the arrival of the wheel at A, that it had made an entire revolution, and that therefore the index would read 10, equal 10 square inches—viz. the multiplication of the length of the radius Q (5 inches) into the circumference of the wheel R (2 inches).

Now let it be assumed that the implement is to be used for the purpose of measuring another rectangle A B C D, also of 10 inches area, having its sides and ends respectively 2 inches and 5 inches long; so that in this instance (see fig. 4) the ends have the 5-inch measurement in lieu of the 2, and the sides have the 2-inch in lieu of the 5. Once more let the tracer T be moved from C to D; the block M will now have only passed along the groove O a comparatively insignificant distance towards C, and the rod Q will lie at the angle shown, so that it will form the hypotenuse (5 inches long) of a triangle of which the base will be C D (2 inches long). If, now, the tracer T be moved from D to A (5 inches), the block M will make a similar motion in the groove O; and when the tracer T has reached A, the rod Q will have moved parallel to itself, and will be found in the position shown in fig. 5. But, as has already been said when speaking of A A[3] of fig. 2, if a cylinder capable of rotating be caused to move over and in contact with a surface when it is in a position neither parallel with, nor at right angles to, the line of motion, and if it be made to preserve its own parallelism, the result will be a motion compounded of sliding and of rolling, and the amount of the rolling will bear such a relation to the whole motion as the base $m\,n$ bears to the hypotenuse $n\,o$. In the instance, therefore, under consideration the ratio of revolution to the whole motion will be that of 2 to 5; therefore if the zero on the wheel R were brought to the pointer S at the time of setting out from D, it would be found, when the tracer had arrived at the end A of its 5-inch journey D A, that the wheel R would have made just one revolution, and that the figure 10, indicating 10 square inches, would present itself.

From a consideration of the foregoing two cases, it will be seen that the "rate" of rotation of the wheel R, when it moves along the line D A, depends upon the length of the line C D, and the "quantity" of such rotation upon that of the line D A. These two expressions, "rate" and "quantity," will be used hereafter in the above senses.

As an illustration of "rate" and "quantity," suppose that the rectangle of fig. 3 had only been half as long as the one that has been considered, namely $2\frac{1}{2}$ inches, and had been bounded by the line D′ A′; if, then, the tracer had been moved from D′ to A′, the "rate" of revolution of the wheels R &c. would have been one half of the total distance moved through by the tracer,

because C D′ (equal $2\frac{1}{2}$ inches) is one half of the length of the rod Q. The "quantity" of motion in going along D′ to A^1 would, however, have been the same as it was in passing from D to A, because D′ A^1 equals D A; but an

Fig. 4.

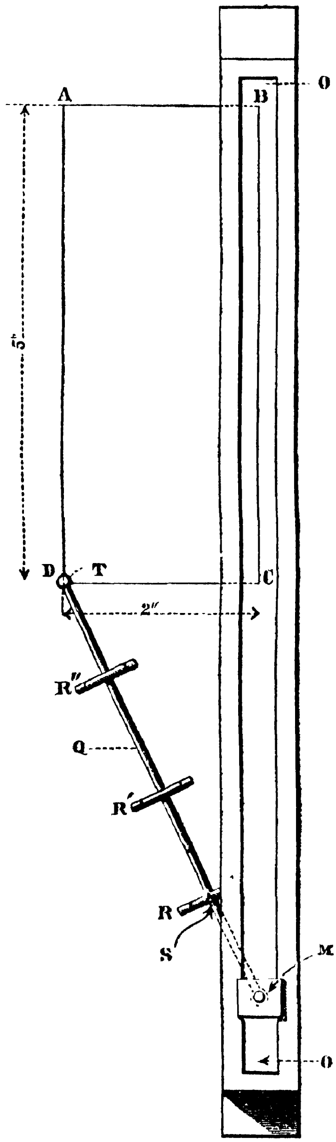
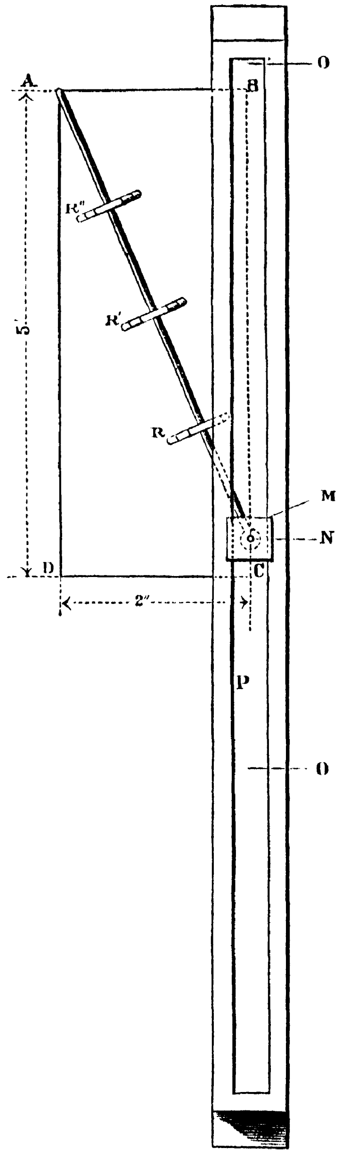


Fig. 5.



equal "quantity" into half the "rate" will only give half the total amount, and therefore the wheels R would have recorded a half revolution, equal 5 square inches, thus accurately giving the area C D′, A^1 B. On the other hand,

assume that the height of the rectangle had been halved, and that it had been bounded by the lines C D, D″ B¹, then the wheels R &c. in traversing from D to D″ would do so at their full "rate" of revolution, the line C D being 5 inches long; but the "quantity" of such revolution would only be half that which it was in going from D to A, because D D″ is only half D A, and therefore the wheels again would register but a half revolution, indicating truly the 5-inch area of the 5-inch by 1-inch parallelogram D D″, B¹ C.

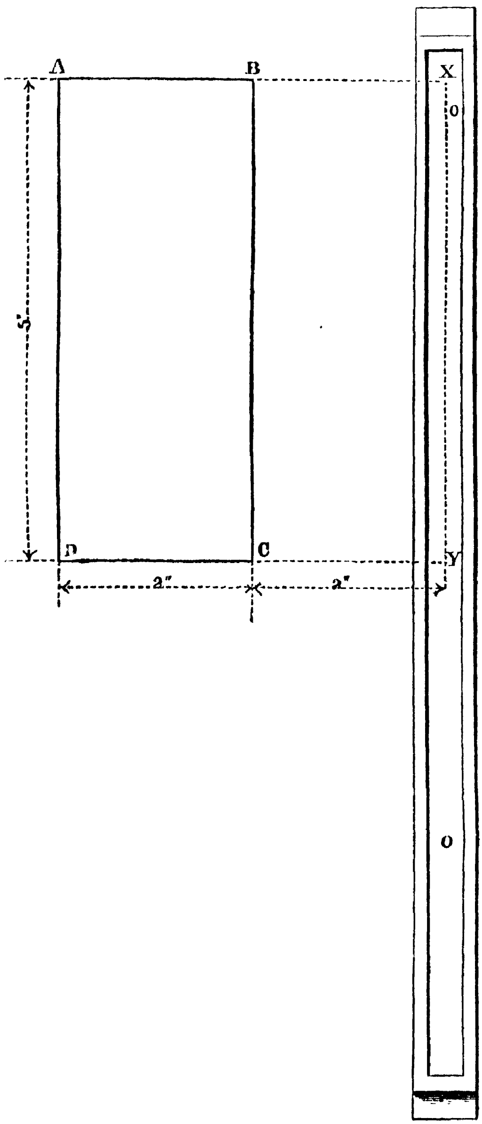
In each of the foregoing cases it has been assumed that the index is read when the apparatus is about to start from D, and is re-read when it reaches A. Such a reading would be quite sufficient in the case of a rectangle where the groove O O is assumed to be in the prolongation of one of the sides (B C); but under any other circumstances the complete circuit of the figure must be made. To test this, let it be assumed that the tracer T starts from C, and that the index on R is read just before the starting, and then let it be examined when the tracer T has reached D; it will be found that the wheel R has received an amount of rotation approximately that due to its traversing the arc of the radius N R, that R′ has received a larger amount of traverse, and R″ a still larger amount, owing to their greater distance from the centre N; but it will be afterwards found that these amounts of revolution may be wholly neglected, and that they will not come into the final computation, because, assume the tracer T to have attained to the point A and to have put into the wheels R, R′, R″ the one revolution which it has been seen that traverse would give, those wheels would be found at A (were there any means by multiplying gear, as in the actual machine, to record more than the one revolution) to have made the one revolution each, plus the varying amounts of revolution which they would have received in their journey from C to D. But in their back journey from A to B it is manifest they will each of them unwind (if such a phrase may be used) exactly the quantity of revolution which was put into them in moving from C to D. Further, during the passage from B to C to complete the circuit, the direction of motion being parallel with the position of the rod Q, the axle of the wheels R, R′, R″, no rolling movement will be communicated to them, as they will be in the condition of the cylinder $A A^2$ of fig. 2, and will merely slide over the paper, so that on the arrival of the tracer T at C, having made the circuit of the rectangle, there will be found in them the one revolution, and neither more nor less than the one revolution, generated by the traverse from D to A.

The next point to be proved is the manner in which the implement will truly record if the groove O O be not on the line produced by prolonging one side of the rectangle. Let fig. 6 represent a rectangle, say 2 inches long on its side C D and 5 inches high at its end D A, and containing therefore 10 square inches, and let X Y be a line parallel with B C, and as far removed (2 inches) on the right hand from it as D A is removed from it on the left hand, and let the groove O O be on the line X Y; then, if the tracer T were to stand at C, and the wheels R &c. were at zero, and if the tracer were then moved along the line C B, there would be put an amount of revolution into R which would be compounded of the "rate" due to the length Y C and of the "quantity" belonging to the length C B, or 2 multiplied by 5 equal 10 inches, equal one revolution of R. But if now the tracer T be brought back again along the line B C, the wheel R will unwind the revolution that was put into it, and on its return to C will be found at zero.

Having thus premised that during the passage of the tracer T from B to C the wheel R will have unwound or made a negative quantity expressive of the rectangle B X Y C, let the measurement of A B C D be considered. As-

sume the tracer to start from C, and the wheels R &c. to be at zero, then in the passage from C to D varying revolutions would be put into these wheels corresponding approximately with the length of their arcs about the centre N;

Fig. 6.



then, on the arrival of the tracer at D, the ratio for the "rate" of trace between D and A will be established, viz. the proportion which Y D (4 inches) bears to the 5-inch length of Q, equal four fifths of the motion which the tracer T is about to make along D A; but the distance D A is 5 inches, and therefore

the wheels R &c. will make a further 4 inches of circumferential movement, equal 2 revolutions, indicating 20 square inches. If, now, the tracer T be moved from A to B, there will clearly be unwound from all the wheels R &c. the amount of motion that was put into them in traversing from C to D, and thus the wheels R &c. will all be left with the double revolution indicative of 20 square inches. The only side remaining to be passed over is that from B to C; and if this traverse were devoid of effect on the wheels R &c., as the traverse from B to C was in the cases of figures 3, 4, and 5, then the implement on arriving at C, at the end of the circuit, would record double the proper area, or 20 inches instead of 10; but in the outset of this paragraph it was shown that the journey from B to C in fig. 6 would unwind exactly one revolution of the wheel R, leaving therefore one revolution remaining, indicating, as it should do, 10 square inches for the area of A B C D.

The next step is to show the ability of the implement to give the area correctly of figures which are not rectangular. Assume, as in figure 7, it be

Fig. 7.

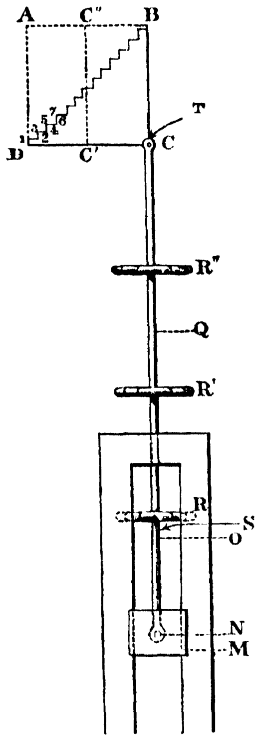
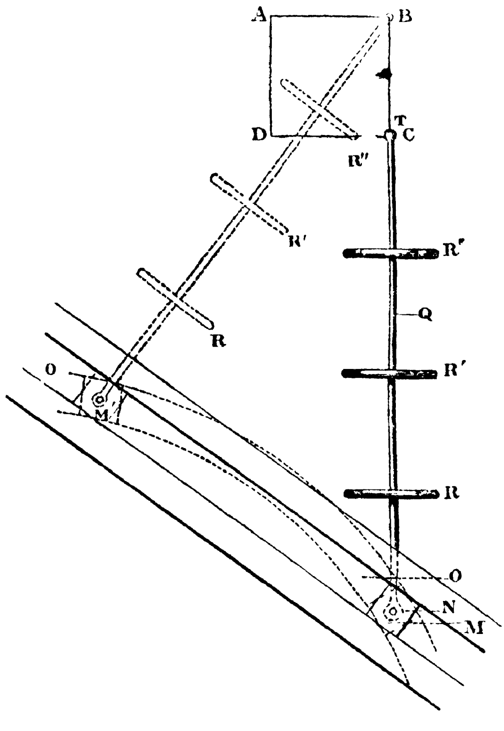


Fig. 8.



required to find the area of the triangle B C D, and let it be imagined that in lieu of the straight line for the hypotenuse B D the boundary of the figure on that side were made by a number of extremely small steps, as sketched; if then the tracer T be made once more to traverse from C to D, the wheel R will have a certain amount of revolution given to it; and if it then be made to rise through the space D 1, it will have a "rate" of revolution equal to the length of the line C D, and a "quantity" equal to the height D 1; if it then

pass along the horizontal line 1 2, it will unwind that proportion of the revolution, put in on going from C to D, that is represented by the length of the line 1 2. If, now, it be made to rise from 2 to 3, it will have a "rate" of revolution equal to the length of the line C D—1 2, and a "quantity" equal to the height of the line 2 3. If it now be carried along the horizontal line 3 4, another portion of the revolution given by C D will be taken out; and then if it be made to rise from 4 to 5, a further portion of a revolution will be put in, having for its "rate" the length of the line C D—D 4, and for its "quantity" the height of the line 4 5. This may be followed through all the steps into which the hypotenuse has been broken up, and then it will be found, as is obvious, that the sum of all the horizontal lines 1 2, 3 4, 5 6, &c. is equal to the length C D, and that the traversing of them will therefore have unwound all the revolution that the passage along C D had put into the wheel R; but it will also be found that the sum of all the vertical lines 2 3, 4 5, 6 7, &c. is equal to D A; and therefore the "quantity" of revolution given to the wheel R will be equal to that which it would have had, had it passed up the line D A, while the means of the lengths of C D—1 2, C D—D 4, C D—D 6, &c. will exactly equal the half of C D, and thus the condition of the wheel R in relation to the index S will, when it arrives by the zigzag path at B, be precisely the same as it would have been if it had gone by the way of the rectangle C C′ C″ B, C C′ being half of C D. A large number of very small steps have been taken in lieu of the straight line hypotenuse D B. Obviously a greater number of much smaller steps, or an infinite number of infinitely little steps, may be substituted, until the traverse ceases to be made along steps at all, and becomes one along the slope line D B, in which condition of things the wheel R at any part of the traverse of the tracer along the hypotenuse is making a revolution compounded of the "rate" due to its horizontal distance from C, and of a "quantity" equal to the rise from D. The "quantity" remains constant during the whole journey, but the "rate" regularly diminishes, and the mean of all the "rates" is that due to the proportion that half the length of the line C D bears to N T, the length of Q.

Now if it has been proved that this elementary planimeter, no matter where anchored, can act efficiently in ascertaining the area of rectangles and of triangles, it is self-evident that it could truly ascertain the area of any other figure, because there is no figure from that of the regular circle to that of the most irregular boundary which cannot be represented by an indefinite number of straight lines lying at various angles—that is to say, a circle is only a polygon of an infinite number of sides, all equal; and any irregular figure may be divided into an indefinite number of sides, most probably unequal.

It may now be said that the elementary planimeter has been shown to have its pivot N attached to the guide-block M working up and down in the straight groove O, that that groove has been sketched with its axis either in the prolongation of B C or in a position parallel to B C, whereas in the actual planimeter there is no such straight groove at all; but the pivot N is at the end of a radius rod, which in its movement causes N to pass through the arc of a circle, and that that arc may have its chord in almost any position in relation to the line B C, and thus there are disturbing causes in the planimeter as manufactured which do not exist in the elementary planimeter. The answer to this objection, which at first sight appears so well-grounded a one, is that these differences between the real and the elementary planimeter may be left out of consideration altogether, as they really have no effect whatever upon the action of the implement. This can be made clear in a very few words.

Assume, as in fig. 8, that the groove O O were placed at an angle to the prolongation of the line B C. If, now, the tracer T be carried along the straight line from C to B, the block M will have moved along the groove O to M, and the wheel R will be found at R′; this will have communicated an amount of revolution to the wheel R due to its change of position to R; the other two wheels (R′, R″) will also have made movements depending principally on their distance from N. Such revolution of R will be given without reference to any area to be measured by the traverse of the tracer T, for that has merely passed along the straight line C B. But on bringing the tracer T back to C, the block M and wheels R, R′, R″ will be restored to the positions they held at the outset, and in being so restored the whole amount of revolution put into the wheels R &c. will be unwound.

But assume that the tracer T, instead of being carried along the line C B and back again, had been taken along the sides of the square C D A B back to C, the pivot N would return to identically the place that it had before the circuit was commenced; and whether during that circuit N moved in the groove O O as placed parallel to the prolongation of C D in fig. 3, or in it as inclined and as shown by full lines in fig. 8, or inclined and curved as dotted in that figure, could make no difference in the final result, because whatever amount of revolution might be given to the wheels R &c. by the movement of N along the path of the groove O (be that groove straight or curved, inclined or not inclined) would be taken out of them again on the return journey along that same path.

Three wheels (R, R′, R″) have been shown loose on the axle Q of the elementary planimeter; this, as was said, has been done for the mere purpose of illustration, to show that wherever situated they will register just the same.

In the actual machine as manufactured and sold, the position of the wheel is about that which has been given to R, and in this position it serves to support the hinge-joint, and is sufficiently far from the tracer T to get rid of the danger of lifting the wheel from the paper if the tracer T were held a little too high.

It is hoped it has been made clear that one revolution of the wheel R will always express an area equal to the circumference of that wheel multiplied into the length of the rod Q, the radius N T *.

If these elements are constant, the scale of the planimeter reading is constant; but if these be capable of variation, then the scale can be varied. Advantage is taken of this property in the construction of one form of the implement in which the length N T is made adjustable, and thus the instrument may be readily arranged to read either French or English superficial measure.

The purposes for which the planimeter may be applied are very numerous. It gives to the Surveyor the readiest means of calculating the acreage of whole estates or of separate fields. To the Hydraulic Engineer it affords a mode for ascertaining with ease and certainty the drainage area of a country, or the area of the sections of rivers, an important thing when it is desired to obtain the dimensions of numerous sections of a stream to ascertain its hydraulic mean depth. To the Naval Architect it presents itself as an aid in calculating the areas of the successive sections of a vessel, and thus most materially assists him in readily determining not merely the total displacement of a vessel, but those more complex problems which he has to solve.

* The implement as manufactured and sold has a length of radius of about $4\frac{1}{4}''$, and a circumference for the wheel R of about $2\frac{6}{17}''$, giving 10 as the multiplication. It has been stated in the outset that one complete revolution of this wheel records an area of 10 square inches.

To the Mechanical Engineer it is a great boon, as by its use he is enabled rapidly and with accuracy to find the average pressure upon the piston of a steam-engine as given by indicator diagram: all that is necessary is to ascertain the area of the figure, then to divide that area by the length and the mean height; the representative of the average pressure is at once obtained.

There are, no doubt, other instances in which such an implement is of great use, but the writer feels it is unnecessary to adduce them in support of the claim of the planimeter to the consideration of engineers and of men of cognate professions; and he brings his paper to a conclusion with the expression of a hope that he has by the use of plain, in fact homely, description solved the problem which he set himself in the outset, and has made it clear how it is that the area of any figure, however irregular, can be recorded in definite standard units of measurement by the mere passage of a tracer along the perimeter of that figure.

NOTICES AND ABSTRACTS

OF

MISCELLANEOUS COMMUNICATIONS TO THE SECTIONS.

MATHEMATICS AND PHYSICS.

Address by WARREN DE LA RUE, *Esq., D.C.L., Ph.D., F.R.S., V.P.C.S., V.P.R.A.S., President of the Section.*

MY predecessors in this Chair have addressed you on many subjects of high interest in Mathematical and Physical Science: I do not contemplate passing in review the recent discoveries in Astronomy or Physical Science, but intend to confine myself, in the main, to Astronomical Photography; and in selecting this branch of science as the subject of this introductory discourse, I think that I shall have your approval, not only because I have given special attention to that subject, but also because it is about to be applied to the determination of a fundamental element of our system, the solar parallax, by observations of the transit of Venus in 1874, and probably also in 1882.

Nothing is so lastingly injurious to the progress of science as false data; for they endure often through many centuries. False views, even if supported by some amount of evidence, do comparatively little harm; for every one takes a salutary interest in proving their falseness; and when this is done the path to error is closed, and the road to truth is opened at the same moment.

It will be conceded that Photography, when applied to scientific observation, undoubtedly preserves facts. But the question has sometimes been raised, are photographic records absolutely trustworthy representations of the phenomena recorded? If not, what is the extent of truth, and where are the inlets for errors and mistakes? Not only has photographic observation gained a wide range of applications in astronomy, but in every other branch of physical science its help is daily more and more taken advantage of; and although, in speaking of this art, I shall confine myself to astronomy, the observations which I propose to make may be suggestive with reference to other branches of physics.

As an instance of the application of this art to optical physics I may in this place call attention to the very successful delineation of the solar spectrum by Mr. Lewis M. Rutherfurd, of the United States. In Mr. Rutherfurd's spectrum, obtained by the camera, many portions and lines are shown (in the ultra-violet for instance) which, while imperceptible to the retina of the eye, impress themselves on the sensitive film. As a fact, lines which are single in Ångström's and Kirchhoff's maps, have been recorded by photography as well-marked double lines. I will now review the application of the art to astronomy.

Stellar photography was for some time applied at Harvard-College Observatory, U.S., to double stars, for the purpose of determining by micrometric measurement their relative angle of position and distance. The zero of the angle of position was found by moving the telescope in right ascension after an impression had been taken, and taking a second one on the same plate; this process gave two sets of photographic images on the same plate; and the right line passing through the

series gave the direction of the daily motion of the heavens. The probable error of a single measurement of the photographic distance of the images was found to be $\pm 0''.12$, or somewhat smaller than that of a direct measurement with the common filar micrometer. The late Professor Bond, who applied photography to stellar astronomy, confining himself to stars brighter than the seventh magnitude, discussed the results in various numbers of the 'Astronomische Nachrichten.' No astronomer more unbiased could have been selected to decide on the comparative value of the photographic and direct observational method. His discussion shows that the probable error of the centre of an image was $\pm 0''.051$, and that of the distance of two such centres was $\pm 0''.072$. Adopting the estimate of Struve, $\pm 0''.217$, as the probable error of a single measurement of a double star of this class with a filar micrometer, Professor Bond shows that the measurement of the photographic images would have a relative value three times as great. He derived the further important conclusion, that deficiency of light can be more than compensated for by proportionate increase in the time of exposure. A star of the ninth magnitude would give a photographic image, after an exposure of ten minutes, with the Cambridge equatorial.

In the reproduction of stars by photography, recently undertaken by Mr. Rutherfurd, the objects to be secured being so minute, special precautions were found to be necessary in depicting them upon the sensitive film, so that their impressions might be distinguishable from accidental specks in the collodion plate. To prevent any such chance of mistake, Mr. Rutherfurd secures a double image of each luminary, the motion of the telescope being stopped for a short time (half a minute) between a first and second exposure of the plate; so that each star is represented by two close specks, so to speak, upon the negative, and is clearly to be distinguished by this contrivance from any accidental speck in the film. A map of the heavens is thus secured, very clear though delicate in its nature, but yet one upon which implicit reliance can be placed for the purposes of measurement. Professor Peirce aptly says, "This addition to astronomical research is unsurpassed by any step of the kind that has ever been taken. The photographs afford just as good an opportunity for new and original investigation of the relative position of near stars as could be derived from the stars themselves as seen through the most powerful telescopes. They are indisputable facts, unbiased by personal defects of observation, and which convey to all future times the actual places of the stars when the photographs were taken."

Mr. Asaph Hall, who shared with Professor Bond the work of measuring the photographic images and of reducing the measurements, has very recently subjected the photographic method to a critical comparison, with a view to deciding on its value when applied to the observation of the transit of Venus. He appears, as regards its application to stellar observations, to underestimate the photographic method in consequence of want of rapidity; but he admits that in the case of a solar eclipse, or of the transit of a planet over the sun's disk, it has very great advantages, especially over eye-observations of contacts, inner and outer, of the planet and the sun's limb, and that the errors to which it is subject are worthy of the most thorough investigation. The observation of a contact is uncertain on account of irradiation, and is also only momentary; so that, if missed from any cause, the record of the event is irretrievably lost at a particular station, and long and costly preparations rendered futile. On the other hand, when the sky is clear, a photographic image can be obtained in an instant and repeated throughout the progress of the transit; and even if all the contacts be lost, equally valuable results will be secured if the data collected on the photographic plates can be correctly reduced, as will be proved hereafter to be undoubtedly possible. That the transit of Venus will be recorded by photography may now be announced as certain, as preparations are energetically progressing in England, France, Russia, and America for obtaining photographic records. There is also a probability of Portugal taking part in these observations; for it is contemplated by Señor Capello to transport the Lisbon photoheliograph to Macao. There are at present five photoheliographs in process of construction for the observing parties to be sent out by the British Government, under the direction of the Astronomer Royal, Sir George B. Airy. The Russian Government will supply their own parties with three similar instru-

ments; and I am also having constructed one of my own for this purpose and for future solar observations. All these instruments, made precisely alike, will embody the results of our experience gained during the last ten years in photoheliography at the Kew Observatory whilst belonging to this Association. One only of them, namely the photoheliograph which has been at work for some years at Wilna, is of a somewhat older pattern; but how great an advance even this instrument is on the original at Kew is proved by the delightful definition of the most delicate markings of the sun in the pictures which have reached this country from Wilna.

Hitherto sun-pictures have been taken on wet collodion; but a question has been raised whether it would not be better to use dry plates. On this point M. Struve informs us that in two places (at Wilna, under the direction of Colonel Smysloff, and at Bothkamp, in Holstein, under Dr. Vogel) they have perfectly succeeded in taking instantaneous photographs of the sun with dry plates.

As far, however, as my own experience has gone, I still believe that the wet collodion is preferable to the dry for such observations.

Now, with reference to contact observations, which it must be remembered are by no means indispensable as far as photography is concerned, it may be conceded that there will attach to the record of the internal contact a certain amount of uncertainty, although not so great as that which affects optical observation. The photograph which first shows contact may possibly not be that taken when the thread of light between Venus and the sun's disk is first completed, but the first taken after it has become thick enough to be shown on the plate; and this thickness is somewhat dependent on incidental circumstances—for example, a haziness of the sky, which, although almost imperceptible, yet diminishes the actinic brilliancy of the sun, and might render the photographic image of the small extent of the limb which is concerned in the phenomenon too faint for future measurements. On the other hand, having a series of photographs of the sun with Venus on the disk, we can, with a suitable micrometer (such as I contrived for measuring the eclipse-pictures of 1860, and which since then has been in continuous use in measuring the Kew solar photograms*), fix the position of the centre of each body with great precision. But the reduction of the measured distances of the centre to their values in arc is not without difficulty. Irradiation may possibly enlarge the diameter of the sun in photographic pictures, and it may diminish the size of the disk of a planet crossing the sun, as is the case with eye-observations; but if the images depicted are nearly of the same size at all stations whose results are to be included in any set of discussions, then the ratio of the diameters of Venus and the sun will be the same in all the plates, and it will be safe to assume that they are equally affected by irradiation. The advantage which, therefore, will result by employing no less than eight instruments precisely alike, as are those now being made by Mr. Dallmeyer on the improved Kew model, is quite obvious. If other forms of instruments, such as will hereafter be alluded to, be used, it will be essential that a sufficient number of them be employed in selected localities to give also connected sets for discussion.

To give some idea of the relative apparent magnitudes of the sun and Venus, I may mention that at the epoch of the transit of 1874 the solar disk would, in the Kew photoheliograph, have a semidiameter of 1965·8 thousandths of an inch, or nearly two inches; Venus a semidiameter of 63·33 of these units; and the parallax of Venus referred to the sun would be represented by 47·85 such units, the maximum possible displacement being 95·7 units or nearly $\frac{1}{10}$ of an inch.

When the photographs have been secured, the micrometric measurements which will have to be performed consist in the determination of the sun's semidiameter in units of the scale of the micrometer, the angle of position of the successive situations of the planet on the disk, as shown on the series of photographs, and finally the distances of the centres of the planet and the sun. These data determine absolutely the chord along which the transit has been observed to within $0''{\cdot}1$; and an error of $1''$ in the measurement would give an error of only $0''{\cdot}185$ in the deduced

* In this micrometer, which is capable of giving radial distances, angles of position, and also rectangular coordinates, the accuracy of linear measurements does not depend on the doubtful results given by a long run of a micrometer screw.

solar parallax. Moreover the epoch of each photographic record is determinable with the utmost accuracy, the time of the exposure being from $\frac{1}{30}$ to $\frac{1}{100}$ of a second or even less.

Now, although the truth of the foregoing remarks will be fully admitted, it will yet be well to point out in this place the inherent or the supposed defects of the photographic method. These defects may principally be comprised under the head of Possibility of Distortion; and the importance of an investigation into this source of error will appear at once obvious in all cases where the position of a definite point with reference to a system of coordinates has to be determined from measured photographs, especially in such a refined application of it as that which it will have in the determination of the solar parallax.

The distortion of a photographic image, if such exist, may be either extrinsic or intrinsic—that is, either optical or mechanical. The instrumental apparatus for producing the image may produce optical irregularities before it reaches the sensitive plate; or an image optically correct may, by irregular contraction of the sensitive film in the process of drying, and other incidents of the process, present on the plate a faulty delineation *.

In general, two ways present themselves for clearing observations from errors. Either methods may be devised for determining the numerical amount of every error from any source, or by special contrivances the source of error may be contracted to such insignificant limits that its effect in a special case is too minute to exert any influence upon the result. Both these roads have been followed in the inquiry into the optical distortion of photographic images.

As regards the first, let it be supposed that, as in the Kew instrument, the primary image is magnified by a system of lenses before reaching the sensitive plate. The defects inherent to the optical arrangement will clearly affect every photographic picture produced by the same instrument; and hence a method suggests itself for determining absolutely the numerical effect of distortion at every point of the field. Let us assume that the same object, which may be a rod of unalterable and known length, be photographed in precisely the same manner in which celestial events are photographically recorded, the object being at a considerable distance; it may successively be brought into all possible positions in the field of the photoheliograph, and the length of the image on the photograph may be measured afterwards at leisure by means of a micrometer. These lengths will change relatively wherever distortion takes place; but by laying down these varying lengths we shall obtain an optical distortion-map of the particular instrument; and tables may be constructed giving in absolute numbers the corrections to be applied to measurements of positions on account of the influence of optical distortion. In this way the optical distortion of the combined object-glass and secondary magnifier is ascertained. The chief source of distortion, if such exist, will be in the secondary magnifier; and in order to ascertain its amount a reticule of lines drawn at equal distances upon glass may (as has been done recently by Paschen and Dallmeyer) be placed in the common focus of the object-glass and secondary magnifier. The required data are then immediately given by the measurement of the resulting pictures of the parallelograms on the reticule. Mr. Dallmeyer has ascertained in this manner that no sensible distortion exists in the secondary magnifier constructed by him. The truth of the principle being granted, it was applied to a preliminary series for finding the distortion which affects the Kew instrument, which is not nearly so perfect as those more recently constructed; and the results were so far satisfactory that, instead of a single rod, a proper scale, fifteen feet in length, representing a series of rectangles distributed over half the radius of the field, has been erected; and the process of absolutely determining the optical distortion of the Kew photoheliograph is now in active progress, and will be used for the new instruments to be employed in observing the transits of Venus.

* It has been proposed, in order to obviate any possible alteration of the sensitive surface, to use the Daguerréotype instead of the collodion process. The former, however, is so little practised, and, moreover, is so much more troublesome, that it does not seem to be advisable to adopt it, especially as the subsequent measurements would present greater difficulties than occur with collodion pictures.

The second method of dealing with optical distortion aims at total exclusion of this source of error. It has been proposed by American astronomers, who intend taking part in the coming observations of the transit of Venus, to exclude the secondary magnifier, and, in order to obtain an image of sufficient diameter, to employ a lens of considerable focal length, say 40 feet, which would give an image as large as with the Kew photoheliograph—namely, 4 inches in diameter. As it would be inconvenient to mount such an instrument equatorially, it is proposed to fix it in the meridian in a horizontal position, and reflect the sun in the direction of its axis by means of a flat mirror moved by a heliostat. There cannot be any doubt about the fact that the image so produced would be nearly free from optical distortion, if the interposed mirror did not introduce a new source of error. The difficulty of producing a plane mirror is well known; and there is a difficulty in maintaining its true figure in all positions; there is also a liability of the disturbance of the rays by currents of heated air between the mirror and object-glass: moreover, with such an instrument position-wires could not be defined with sharpness on the photographs. On the whole, greater reliance may be placed on a method which admits the existence of a distorting influence, but has at the same time means of checking and controlling it numerically.

Great attention has been paid by me at various times to those effects of distortion which might arise from the process of drying. The results to which the experiments lead seem to prove that there is no appreciable contraction except in thickness, and that the collodion film does not become distorted, provided the rims of the glass plates have been well ground: this point is a fundamental one. But in such observations as that of the transit of Venus, no refinement of correction ought to be neglected; hence fresh experiments will be undertaken to set at rest the question whether distortion of the film really takes place when proper precautions are taken. This will be done both by the method I have employed before, and also in accordance with M. Paschen's proposal to measure images of such reticules as above described: this reticule might, as he has suggested, be photographed during the transit of Venus, so that each plate would thus bear data for the correction due to unequal shrinkage, if such were to take place.

It has been objected by some astronomers who have casually examined solar photograms that the limb of the sun appears, as a consequence of the gradual shading off, even under a small magnifying-power, not bounded by a sharp contour; but the measurements of such photograms which have been made during the last ten years, of pictures taken under the most varying conditions which influence definition, have proved that even the worst picture leads to a very satisfactory determination of the sun's semidiameter and centre; moreover an independent examination of this question by M. Paschen gave as the result that the mean error of a determination is only $\pm$ 0·008 millimetre with a sun-picture of 4 Paris inches in diameter; this corresponds to $\pm$ 0″·135, and it is nearly three times less than that resulting from a measurement with the Königsberg heliometer.

Nevertheless it will be seen from the foregoing remarks that I have not hesitated to arouse your attention to the fact that Astronomical Photography is about to be put to the severest test possible in dealing with such a fundamental problem of astronomy as the determination of the sun's distance from the earth. An intimate knowledge of the subject, however, and experience with respect to work already accomplished in the Kew ten-year solar observations, inspire me with a confident anticipation that it will prove fully equal to the occasion.

So much for performances to be looked forward to in the future: now let me briefly review what Astronomical Photography has already undoubtedly accomplished.

In the first instance the possibility proved of giving to the photographic method of observation a trustworthiness which direct observations can never quite obtain, will render the results of our discussion of the ten years' solar observations at Kew more free from doubts than those observational series on the Sun's spots which have preceded ours. The evidence of a probable connexion between planetary positions and solar activity, and the evidence which we have published on the nature of spots as depressions of solar matter, could never have been brought forward but for the preservation of true records of the phenomena through a number of years;

while the closer agreement of the calculated results in reference to solar elements is itself evidence of the intrinsic truthfulness of the method, and gives the highest promise that our final deductions, which will be completed in the course of the ensuing year, will not be unworthy of the exertions which I, in conjunction with my friends B. Stewart and B. Loewy, have constantly devoted to this work during a period of fully ten years. Not only will some doubtful questions be set finally at rest by it, but new facts of the greatest interest will result, bearing on the laws which appear to govern solar activity.

By nothing, however, would the claims of photographic observation, as one of the most important instruments of scientific research, seem to be so thoroughly well established as by the history of recent solar eclipses. It will be recollected that in 1860, for the first time, the solar origin of the prominences was placed beyond doubt solely by photography, which preserved a faithful record of the moon's motion in relation to these protuberances. The photographs of Tennant at Guntour, and of Vogel at Aden, in 1868, and also those of the American astronomers at Burlington and Ottumwa, Iowa, in 1869, under Professors Morton and Mayer, have fully confirmed those results. In a similar manner the great problem of the solar origin of that portion of the corona which extends more than a million of miles beyond the body of the sun has been, by the photographic observations of Col. Tennant and Lord Lindsay in 1871, set finally at rest, after having been the subject of a great amount of discussion for some years.

The spectroscopic discovery in 1869 of the now famous green line, 1474 K, demonstrated undoubtedly the self-luminosity, and hence the solar origin of part of the corona. Those who denied the possibility of any extensive atmosphere above the chromosphere received the observation with great suspicion; but in 1870 and again in 1871 it was fully verified. So far, therefore, the testimony of spectroscopic observations was in favour of the solar origin of the inner corona.

Indeed the observations of 1871 have proved hydrogen to be also an essential constituent of the "coronal atmosphere," as Janssen proposes to call it,—hydrogen at a lower temperature and density, of course, than in the chromosphere. Janssen was further so fortunate as to catch glimpses of some of the dark lines of the solar spectrum in the coronal light, an observation which goes far to show that in the upper atmosphere of the sun there are also solid or liquid particles, like smoke or cloud, which reflect the sunlight from below. Many problems, however, even with reference to the admittedly solar part of the corona, are unsettled. The first relates to the nature of the substance which produces the line 1474 K. Since it coincides with a line in the spectrum of iron, it is by many considered due to that metal; but then we must suppose either that iron vapour is less dense than hydrogen gas, or that it is subject to some peculiar solar repulsion which maintains it at its elevation; or other hypotheses may be suggested for explaining the fact. Since the line is one of the least conspicuous in the spectrum of iron and the shortest, and as none of the others are found associated with it in the coronal spectrum, it seems natural, as many have done, to assume at once that it is due to some new kind of matter. But the observations of Ångström, Roscoe, and Clifton, and recently those of Schuster regarding the spectrum of nitrogen, render it probable that elementary bodies have only one spectrum; and since in all experimental spectra we necessarily operate only on a small thickness of a substance, we cannot say what new lines may be given out in cases where there is an immense thickness of vapour; and hence we cannot conclude with certainty that because there is an unknown line in the chromosphere or corona, it implies a new substance. Another problem, the most perplexing of all, is the reconciliation of the strangely discordant observations upon the polarization of the coronal light; but I will at once proceed to the points on which photography alone can give us decisive information.

The nature and conditions of the outer corona (the assemblage of dark rifts and bright rays which overlies and surrounds the inner corona) was very incompletely studied; and the question whether it is solar was not finally settled in the opinions of astronomers of high repute. Some believed it to be caused by some action of our atmosphere; and others supposed it due to cosmical dust between us and the moon. The bright light of the corona and the prominences most undoubtedly cause a certain amount of atmospheric glare; and although it is difficult to see how

this is to account for the rays and rifts, it would be rash to deny that it may do so in some manner yet to be discovered. It is quite certain that some of the phenomena observed just at the beginning and end of totality are really caused by it. A light haze of meteoric dust between us and the moon might give results much resembling those observed; but when we come to details this theory seems to be doubtful.

Here photography steps in to pave the way out of the existing doubts. If the rays and rifts were really atmospheric, it would hardly be possible that they should present the same appearance at different stations along the line of totality; indeed they would probably change their appearance every moment, even at the same station. If they are cislunar, the same appearances could not be recorded at distant stations. It is universally admitted that proof of the invariability of these markings, and especially of their identity as seen at widely separated stations, would amount to a demonstration of their extraterrestrial origin. Eye-sketches cannot be depended on; the drawings made by persons standing side by side differ often to an extent that is most perplexing. Now photographs have, undoubtedly, as yet failed to catch many of the faint markings and delicate details: but their testimony, as far as it goes, is unimpeachable. In 1870, Lord Lindsay at Santa Maria, Professor Winlock at Jerez, Mr. Brothers at Syracuse, obtained pictures some of which, on account partly of the unsatisfactory state of the weather, could not compare with Mr. Brothers's picture obtained with an instrument of special construction*; but all show one deep rift especially, which seemed to cut down through both the outer and inner corona clear to the limb of the moon. Even to the naked eye it was one of the most conspicuous features of the eclipse. Many other points of detail also come out identical in the Spanish and Sicilian pictures; but whatever doubts may have still existed in regard to the inner corona were finally dispelled by the pictures taken in India, in 1871, by Colonel Tennant and Lord Lindsay's photographic assistant, Mr. Davis.

None of the photographs of 1871 shows so great an extension of the corona as is seen in Mr. Brothers's photograph, taken at Syracuse in 1870; but, on the other hand, the coronal features are perfectly defined on the several pictures, and the number of the photographs renders the value of the series singularly great. The agreement between the views, as well those taken at different times during totality as those taken at different stations, fully proves the solar theory of the inner corona. We have in all the views the same extensive corona, with persistent rifts similarly situated. Moreover there is additional evidence indicated by the motion of the moon across the solar atmospheric appendages, proving in a similar manner as in 1860, in reference to the protuberances, the solar origin of that part of the corona.

It will be well here to mention a difficulty which occurs in recording the fainter solar appendages, namely the encroachment of the prominences and the corona on the lunar disk when the plates have to be overexposed in order to bring out the faint details of the corona. It is satisfactory to find that whenever a difficulty arises it can be mastered by proper attention. Lord Lindsay and Mr. Ranyard have successfully devoted themselves to experiments on the subject. They tested whether reflections from the back surface of the plate played any part in the production of the fringes: for this purpose plates of ebonite and the so-called non-actinic yellow glass were prepared: and it was immediately found that the outer haze had completely disappeared in the photographs taken on ebonite, while on the yellow glass plates it is much fainter than on ordinary white glass plates. By placing a piece of wetted black paper at the back of an unground plate, the outer haze was greatly reduced; but by grinding both the back and the front surfaces of a yellow glass plate, and covering the back with a coating of black varnish, it was rendered quite imperceptible, thus showing the greatest part of the so-called photographic irradiation to be due to reflection from the second surface.

* Mr. Brothers had, in 1870, the happy idea to employ a so-called rapid rectilinear photographic lens, made by Dallmeyer, of 4 inches aperture and 30 inches focal length, mounted equatorially, and driven by clockwork; and he was followed in this matter by both Col. Tennant and Lord Lindsay in 1871. The focal image produced, however, is far too small ($\frac{3}{10}$ of an inch, about); therefore it will be desirable in future to prepare lenses of similar construction, but of longer focal length and corresponding aperture.

In connexion with the solution of the most prominent questions connected with the solar envelopes, it may not be without great interest to allude to another point conclusively decided during the last annular eclipse of the sun, observed by Mr. Pogson on the 6th of June of this year, as described by him in a letter to Sir George B. Airy. In 1870 Professor Young was the first to observe the reversal of the Frauenhofer lines in the stratum closest to the sun. Now, in 1871 doubts were thrown upon the subject. It appears that the reversed lines seem to have been satisfactorily observed by Captain Maclear at Bekul, Colonel Tennant at Dodabetta, and Captain Fyers at Jaffna. The observations of Pringle at Bekul, Respighi at Paodoxottah, and Pogson at Avenashi were doubtful; while Mosely at Trincomalee saw nothing of this reversal, which is, according to all accounts, a most striking phenomenon, although of very short duration. Mr. Lockyer missed it by an accidental derangement of the telescope. The reversal and the physical deductions from it are placed beyond doubt by Mr. Pogson's observations of the annular eclipse on June 6th. At the first internal contact, just after a peep in the finder had shown the moon's limb lighted up by the corona, he saw all the dark lines reversed and bright, but for less than two seconds. The sight of beauty above all was, however, the reversion of the lines at the breaking-up of the limb. The duration was astonishing—five to seven seconds; and the fading-out was gradual, not momentary. This does not accord with Captain Maclear's observations in 1870, who reports the disappearance of the bright spectrum as "not instantly, but so rapidly that I could not make out the order of their going." Professor Young again says that "they flashed out like the stars from a rocket-head." But discrepancies in this minor point may be accounted for by supposing differences in quietude of that portion of the sun's limb last covered by the moon.

The mention of the solar appendages recalls to mind another instance in which photography has befriended the scientific investigator. I allude to the promising attempt which has been made by Professor Young to photograph the protuberances of the sun in ordinary daylight. A distinct reproduction of some of the double-headed prominences on the sun's limb was obtained; and although as a picture the impression may be of little value, still there is every reason to believe, now that the possibility of the operation is known, that with better and more suitable apparatus an exceedingly valuable and reliable record may be secured. Professor Young employed for the purpose a spectroscope containing seven prisms, fitted to a telescope of $6\frac{1}{2}$-inch aperture, after the eyepiece of the same had been removed. A camera, with the sensitive plate, was attached to the end of the spectroscope, the eyepiece of which acted in the capacity of a photographic lens, and projected the image on the collodion film. The exposure was necessarily a long one, amounting to three minutes and a half. The eyepiece of the spectroscope was unsuitable for photographic purposes, and only in the centre yielded a true reproduction of the lines free from any distortion. A larger telescope, with a suitable secondary magnifier, will be required in order to secure a more defined image.

I have hitherto spoken of the successful applications of photography to astronomy; but I must point out also some cases where it has failed. Nebulæ and comets have not yet been brought within the grasp of this art, although, perhaps, no branch of astronomy would gain more if we should hereafter succeed in extending to these bodies that mode of observing them. There is theoretically, and even practically, no real limit to the sensitiveness of a plate. Similarly with reference to planets great difficulties still exist, which must be overcome before their phases and physical features can be recorded to some purpose by photography; yet there is great hope that the difficulties may be ultimately surmounted. The main obstacle to success arises from atmospheric currents, which are continually altering the position of the image on the sensitive plate; the structure of the sensitive film is also an interfering cause for such small objects. A photograph taken at Cranford of the occultation of Saturn by the moon some time ago exhibits the ring of the planet in a manner which holds out some promise for the future.

The moon, on the other hand, has been for some time past very successfully photographed; but no use has hitherto been made of lunar photographs for the purposes of measurement.

The photographs of the moon are free from distortion, and offer therefore

material of incalculable value as the basis of a selenographic map of absolute trustworthiness, and also for the solution of the great problem of the moon's physical libration. This question can be solved with certainty by a series of systematic measurements of the distance of definite lunar points from the limb. Mr. Ellery, Director of the Observatory of Melbourne, has sent over an enlargement of a lunar photograph taken with the Great Melbourne Telescope, in which the primary image is $3\frac{3}{16}$ inches in diameter. Such lunar negatives would be admirably adapted for working out the problem of the physical libration, and also for fundamental measurements for a selenographic map; the more minute details, however, would have to be supplied by eye-observations, as the best photograph fails to depict all that the eye sees with the help of optical appliances. On the other hand, selenographic positions would be afforded more free from error than those to be obtained by direct micrometrical measurements.

Although, as I have stated, I do not contemplate passing in review recent discoveries in astronomy, I must not omit to call your attention to some few subjects of engrossing interest. First, with reference to the more recent work of Dr. Huggins. In his observations he found that the brightest line of the three bright lines which constitute the spectrum of the gaseous nebulæ was coincident with the brightest of the lines of the spectrum of nitrogen; but the aperture of his telescope did not permit him to ascertain whether the line in the nebulæ was double, as is the case with the line of nitrogen. With the large telescope placed in his hands by the Royal Society, he has found that the line in the nebulæ is not double, and in the case of the great nebula in Orion it coincides in position with the less refrangible of the two lines which make up the corresponding nitrogen-line. He has not yet been able to find a condition of luminous nitrogen in which the line of this gas is single and narrow and defined like the nebular line.

He has extended the method of detecting a star's motion in the line of sight by a change of refrangibility in the line of a terrestrial substance existing on the star to about 30 stars besides Sirius. The comparisons have been made with lines of hydrogen, magnesium, and sodium. In consequence of the extreme difficulty of the investigation, the numerical velocities of the stars have been obtained by estimation, and are to be regarded as provisional only. It will be observed that, speaking generally, the stars which the spectroscope shows to be moving from the earth, as Sirius, Betelgeux, Rigel, Procyon, are situated in a part of the heavens opposite to Hercules, towards which the sun is advancing; while the stars in the neighbourhood of this region, as Arcturus, Vega, and α Cygni, show a motion of approach. There are, however, in the stars already observed, exceptions to this general statement; and there are some other considerations, as the relative velocities of the stars, which appear to show that the sun's motion in space is not the only or even in all cases the chief cause of the observed proper motions of the stars. In the observed stellar motions we have to do probably with two other independent motions—namely, a movement common to certain groups of stars and also a motion peculiar to each star. Thus the stars β, γ, δ, ϵ, ζ of the Great Bear, which have similar proper motions, have a common motion of recession; while the star α of the same constellation, which has a proper motion in the opposite direction, is shown by the spectroscope to be approaching the earth. From further researches in this direction, and from an investigation of the motions of stars in the line of sight in conjunction with their proper motions at right angles to the visual direction obtained by the ordinary methods, we may hope to gain some definite knowledge of the constitution of the heavens.

This discovery supports, in a somewhat striking manner, the views which Mr. Proctor has been urging respecting the distribution of the stars in space. According to these views there exist within the sidereal system subordinate systems of stars forming distinct aggregations, in which many orders of real magnitude exist, while around them is relatively barren space. He had inferred the existence of such systems from the results of processes of equal-surface charting applied successively to stars of gradually diminishing orders of brightness. He found the same regions of aggregation, whether the charts included stars to the sixth order only or were extended, as in his chart of the northern heavens, to the tenth and eleventh orders; and these regions of aggregation are the very regions

where the elder Herschel found the faintest telescopic stars to congregate. Applying a new system of charting to show the proper motions of the stars, he found further evidence in favour of these views. The charts indicated the existence of concurrent motions among the members of several groups or sets of stars. Selecting one of the more striking instances as affording what appeared to him a crucial test of the reality of this *star-drift*, Mr. Proctor announced his belief that whenever the spectroscopic method of determining stellar motions of recess or approach should be applied to the five stars β, γ, δ, ϵ, and ζ Ursæ Majoris, these orbs (which formed a drifting set in the chart of proper motions) would be found to be drifting collectively either towards or from the earth: this has been confirmed.

The time has now come for more closely investigating the various theories which have been propounded by such profound thinkers as Tyndall, Tait, Reynolds, and others, to account for the phenomena of Comets. I do not propose to enter into a statement of these theories; but I venture to call your attention to Zöllner's views, which have recently given rise to a great amount of controversy. In doing so, I am solely influenced by a desire to give information on this subject, without implying thereby that I give my adherence, or even preference, to his theory *.

The vaporization of even solid bodies at low temperatures suggests that a mass of matter in space will ultimately surround itself with its own vapour, the tension of which will depend upon the mass of the body (that is, upon its gravitative energy) and the temperature. If the mass of the body is so small that its attractive force is insufficient to give to the enveloping vapour its maximum tension for the existing temperature, the evolution of vapour will be continuous until the whole mass is converted into it. It is proved by analysis that such a mass of gas or vapour in empty and unlimited space is in a condition of unstable equilibrium, and must become dissipated by continual expansion and consequent decrease of density. It follows that celestial spaces, at least within the limits of the stellar universe, must be filled with matter in the form of gas.

A fluid mass existing in space at a distance from the sun or other body radiating heat would, if its mass were not too great, be converted entirely into vapour after the lapse of sufficient time. But if the fluid mass approach the sun, solar heat would occasion a more rapid development of vapour on the sunward side; and the total vaporization would require an incomparably short time with reference to the interval necessary in the former case; this time would be shorter the smaller the mass of the body. Professor Zollner points to the smaller comets, which often appear as spherical masses of vapour, as examples of such bodies, while the spectra of some of the nebulæ and smaller comets render the existence of fluid masses giving out vapour highly probable.

The self-luminosity and train of comets he refers to other causes. Two causes only are known through the operation of which gases become self-luminous—elevation of temperature (as by combustion), or electrical excitement. Setting aside the first as involving theoretical difficulties, the second cause is demonstrated by him to be sufficient to account for the self-luminosity and the formation of the train, provided it be granted that electricity may be developed by the action of solar heat, if not in the process of evaporation, at least in the mechanical and molecular disturbances resulting from it. The production of electricity by such processes within the limits of our experience must be admitted as a well-known fact. The spectrum of the vaporous envelope of a comet, illuminated in this manner, must necessarily be that produced by the passage of an electrical discharge through vapour identical in substance with a portion of the comet's nucleus, from which the envelope is derived. As, according to this supposition, water and liquid hydrocarbons are important constituents of these bodies, the spectra of the comets should be such as belong to the vapours of these substances; and in this manner the resemblance and partial coincidence of the observed cometic spectra with those of gaseous hydrocarbons is explained.

The form and direction of the train indicate undoubtedly the action of a repulsive force; and Professor Zöllner asserts that the assumption of an electrical action of the sun upon bodies of the solar system is necessary and sufficient to account for all the essential and characteristic phenomena of the vaporous envelope and

* See Appendix, p. 12.

the train. The direction of the train, towards or from the sun, is, according to this theory, to be easily explained by the supposition of a variability in the mutual electrical conditions. This accords perfectly with the phenomena observed in the development of electricity by vapour-streams in the hydroelectric machine, where the sign of the electricity depends upon the presence or absence of various substances in the boiler or the tubes.

The theory acquires an additional interest from Schiaparelli's remarkable discovery of the identity of the paths of certain comets with great meteor-streams, since the meteoric masses must inevitably be converted into vapour on approaching the sun, with exhibition of the characteristic appearances of the comets.

The intimate connexion of planetary configuration and solar spots, of the latter and terrestrial magnetism and auroral phenomena, must tend to establish also a connexion between solar spots and solar radiation. It is demonstrated, by the researches of Piazzi Smyth, Stone, and Cleveland Abbe, that there is a connexion between the amount of heat received from the sun and the prevalence of spots—a result clearly in harmony with those derived from recent investigations into the nature of the solar atmosphere. Further, in a paper by Mr. Meldrum, of Mauritius, which will be read before you during this session, most remarkable evidence is given on the close connexion of these phenomena. It appears that the cyclones of the Indian Ocean have a periodicity corresponding with the sun-spot periodicity; so that if an observer in another planet could see and measure the sun-spots and cyclones (earth-spots), he would find a close harmony between them. Such a connexion will probably be found to exist over the globe generally; but with reference to the Indian Ocean it may be stated as a matter of fact, from Mr. Meldrum's discussion of twenty-five years' observations, that in the area lying between the equator and 25° south latitude, and between 40° and 110° east longitude, the frequency of cyclones has varied during that period directly as the amount of sun-spots. I am glad to be able to announce that Mr. Meldrum, in order to place the deductions on a still broader foundation, proposes to investigate these laws on a plan perfectly in agreement with our method of determining the areas of solar disturbances, the results of which have been published from time to time during the last ten years. Moreover the observations on the periodic changes of Jupiter's appearance, and the observations of Mr. Baxendell that the convection-currents of our earth vary according to the sun-spot period—all these results, seemingly solitary, but truly in mysterious harmony, point to the absolute necessity for establishing constant photographic records of solar and terrestrial phenomena all over the world. No astronomer or physicist should lose any opportunity of assisting in this great aim, by which alone unbiased truthful records of phenomena can be preserved. What is more, no system of observations can be carried on at a less expense.

We have hopes of seeing the photographic method as applied to sun-observations joined to the work of the Greenwich Observatory; but what is further wanted is the erection of instruments for photographic records and of spectroscopes in a number of observatories throughout the world, so as to obtain daily records of the sun and to observe magnetical and meteorological phenomena continuously in connexion with solar activity. Meteorological observation is storing up useful facts; but they can only be dealt with effectually if investigated in close parallelism with other cosmical phenomena. Only when this is done may we hope to penetrate the maze of local meteorological phenomena and elevate meteorology to the rank of a science. The time has really come not only for relieving private observers from the systematic observation of solar phenomena, but for drawing close ties between all scattered scientific observations, so as to let one grand scheme embrace the whole: and no method seems to be so well adapted to bring about this great achievement than the method of photographing the phenomena of nature, which in its very principle carries with it all extinction of individual bias.

In conclusion I cannot refrain from making a passing allusion to a Royal Commission, presided over by the Duke of Devonshire, which has been sitting for some time past; for I believe that its labours will have an important bearing on all that relates to scientific education and the promotion of science in this country. The time has come when the cultivation of science must be protected and fostered by the state; it can no longer be safely left to individual efforts. If England is to

continue to hold a high position among civilized nations, the most anxious care must be given to the establishment by the state of such an organized system for the advancement of science and the utilization of the work of scientific men as will be in harmony with similar organizations in neighbouring states—for examples, France, Germany, and Russia.

APPENDIX.

Certain conclusions at which Professor Zöllner arrives in the investigation of several points bearing on the theory which he defends are, quite independent of the latter, of high scientific value.

First, with reference to the density of atmospheric air, which (in accordance with the considerations mentioned in stating his views) he supposes to fill the interstellar space everywhere, he assumes for the purposes of calculation that the temperature of space is that of melting ice, and finds that the lower limit of density for a portion of gas in space is $\frac{1}{10^{216}}$ of that of the air at the earth's surface, a value so small that if a mass of air which, at its ordinary density upon the earth's surface, occupies a volume of one cubic decimetre (a litre) were reduced to the density expressed by this fraction, it would fill a sphere whose radius would not be traversed by a ray of light in less than 10^{58} years. These values indicate a density which would have no appreciable effect whatever upon rays of light or upon the motion of bodies in space, and which would become still less if the temperature of space be taken, with Fourier, at $-60°$ C., or with Pouillet, at $-132°$ C. But as every solid body must, by virtue of its gravitative energy, condense the gas into an atmospheric envelope round itself, the density of the latter will solely depend on the size and mass of the body. Professor Zöllner finds by calculation that, for instance, the density of air thus forming an atmosphere round the moon must be $\frac{1}{10^{332}}$ of that of the air of the earth's surface. This is in accord with the fact that no trace of a lunar atmosphere has as yet been detected. But the values become very great for the larger planets, quite great enough to manifest absorptive effects upon the light reflected from them. Considering that there are peculiarities in the spectra of Uranus, Neptune, and also of Jupiter, which appear to indicate atmospheric influences, Professor Zöllner's results are not without deep interest, and certainly suggestive of further inquiry.

Secondly, with reference to the supposition that a body may be at the same time under the influence of gravitative and electrical agencies, it was necessary for the author of this theory to discuss the quantitative difference in their effect upon ponderable masses at a distance. The discussion shows that, if the mass increases, gravitation preponderates over electricity; if the mass decreases sufficiently, the contrary takes place. It follows that the cometary nuclei, as masses, are subject to gravitation, while the attenuated vapours developed from them yield to the action of free electricity of the sun. Professor Zollner has based upon Hankel's numerous and careful researches on the determination of atmospheric electricity, in absolute measure, an analytical inquiry into the motion of a small sphere under the action of gravity and atmospheric electricity, which leads to some remarkable results. Supposing the free electricity of the sun to be not greater than that repeatedly observed on the earth's surface, and to be uniformly distributed, it would communicate to a sphere having a diameter of 11 millimetres and a weight of $\frac{1}{100}$ of a milligramme, and starting from the sun, by the time it had moved as far away as the mean distance of Mercury, a velocity per second of 3,027,000 metres, or 408·4 German geographical miles *. This velocity is such that in two days it would pass over a space of 70,540,000 German geographical miles, a magnitude quite of the same order as those recorded by cometary astronomy. The discussion was undertaken to prove that there is no need for assuming the existence of any unknown repulsive agency, but that electrical energy not greater than that observed on the earth's surface is amply sufficient to account satisfactorily for the phenomena presented by cometic trains.

* Fifteen to a degree of longitude on the Equator.

Mathematics.

On the Contact of Surfaces of the Second Order with other Surfaces.
By Prof. Clifford, *M.A.*

New Improvements in Approximating more rapidly than usual to Square, Cube, and other Roots of a given Number N. *By* Matthew Collins, *A.B. Dublin.*

On Square Roots.

It is plain that $(N^{\frac{1}{2}}-a)^m$, where m is a positive integer and N and a any given numbers, has always, when expanded by the binomial theorem, the form $AN^{\frac{1}{2}}-B$, since

$$(N^{\frac{1}{2}})^3=N\,.\,N^{\frac{1}{2}},\quad (N^{\frac{1}{2}})^4=N^2,\quad (N^{\frac{1}{2}})^5=N^2\,.\,N^{\frac{1}{2}},\quad \&c.$$

Now, by one or two trials or guesses a can be taken so near $N^{\frac{1}{2}}$ that $N^{\frac{1}{2}}-a$ shall be a small fraction $f<\frac{1}{2}$, or even $<\frac{1}{10}$, and then $(N^{\frac{1}{2}}-a)^m=f^m$, i. e. $=AN^{\frac{1}{2}}-B$, which gives

$$N^{\frac{1}{2}}=\frac{B+f^m}{A},\ \therefore\ \text{very nearly}=\frac{B}{A},$$

especially when m is a large integer whose greatness plainly increases A and B, but diminishes f^m, where $f=N^{\frac{1}{2}}-a,\ \therefore=\frac{N-a^2}{N^{\frac{1}{2}}+a},\ \therefore=\frac{N-a^2}{2N^{\frac{1}{2}}}$ nearly, so that f, when positive, is $<\frac{N-a^2}{2a}$ or $\frac{D}{2a}$, where $D=N-a^2$.

Ex. gr. $m=3$ gives

$$N^{\frac{1}{2}}=\frac{(3N+a^2)a+f^3}{3a^2+N}\ \text{exactly},\ \therefore=\frac{3N+a^2}{3a^2+N}a+\frac{f^3}{4N}\ \text{very nearly}$$

(since $a^2=N$ nearly),

$$\therefore=\frac{3N+a^2}{3a^2+N}a\ \text{nearly}\ .\ .\ .\ .\ .\ \text{(A)}$$

as $\frac{f^3}{4N}$ must necessarily be very small indeed. Now this plainly agrees with Dr. Hutton's elegant formula (D), given further on, for approximating to $N^{\frac{1}{n}}$ when $n=2$.

But we can approximate to $N^{\frac{1}{2}}$ still more rapidly than by Dr. Hutton's rule; for by taking $m=5$, we find

$$N^{\frac{1}{2}}=\frac{a(a^4+10Na^2+5N^2)+f^5}{N^2+10Na^2+5a^4}\ \text{exactly},$$

$$\therefore=\frac{5(N+a^2)^2-(2a^2)^2}{5(N+a^2)^2-(2N)^2}\,.\,a+\frac{f^5}{(4N)^2}=a'+f'\ \text{very nearly (since } a^2=N \text{ nearly)},$$

$$\therefore=a'\ \text{or}\ \frac{5(N+a^2)^2-(2a^2)^2}{5(N+a^2)^2-(2N)^2}\,.\,a\ \text{nearly}.\ .\ .\ .\ .\ .\ .\ .\ .\ .\ .\ .\ .\ .\ \text{(B)}$$

Now this last *new* and *elegant* formula approximates to $N^{\frac{1}{2}}$ much more closely than the above-mentioned formula of Dr. Hutton, since the error or supplementary term here omitted, viz. $\frac{f^5}{16N^2}=\frac{f^3}{4N}\,.\,\frac{f^2}{4N}$, is *obviously* much less than $\frac{f^3}{4N}$, its value or amount when Dr. Hutton's rule is used.

Ex. gr. To find $\sqrt{3}$. Let us take $a=2$, and as N is here $=3$, we find by our new formula

$$3^{\frac{1}{2}}=\frac{5\times7^2-8^2}{5\times7^2-6^2}\,.\,2=\frac{362}{209}\ \text{nearly};$$

in fact $\left(\frac{362}{209}\right)^2=3+\frac{1}{(209)^2}$, indicating that $\frac{362}{209}$ is nearer to $\sqrt{3}$ than *any* rational fraction whose denominator is less than 209.

On Cube Roots.

It is plain, as before, when m is a positive integer, that $(N^{\frac{1}{3}}-a)^m$, when expanded by the binomial theorem, has always the form $AN^{\frac{2}{3}}+BN^{\frac{1}{3}}+C$, since

$$(N^{\frac{1}{3}})^2=N^{\frac{2}{3}},\quad (N^{\frac{1}{3}})^3=N,\quad (N^{\frac{1}{3}})^4=N\,.\,N^{\frac{1}{3}},\quad (N^{\frac{1}{3}})^5=N\,.\,N^{\frac{2}{3}},\quad \&c.$$

Now take a, as before, by trial or guess, so that $N^{\frac{1}{3}}-a$ shall be a small fraction $f<\frac{1}{2}$;

$$\therefore\ f^m=(N^{\frac{1}{3}}-a)^m=AN^{\frac{2}{3}}+BN^{\frac{1}{3}}+C\,;$$

and for another integer m' we have

$$f^{m'}=(N^{\frac{1}{3}}-a)^{m'}=A'N^{\frac{2}{3}}+B'N^{\frac{1}{3}}+C'.$$

Now, by eliminating $N^{\frac{2}{3}}$ from these two equations, we easily find

$$N^{\frac{1}{3}}=(A'C-AC'+Af^{m'}-A'f^m)\div(AB'-A'B)\text{ exactly,}$$

and therefore $=\dfrac{A'C+AC'}{AB'-A'B}$ very nearly.

Ex. gr. Taking $m=5$ and $m'=7$, we readily find

$$N^{\frac{1}{3}}=\frac{7N^3+105N^2a^3+120Na^6+11a^9}{N^3+60N^2a^3+147Na^6+35a^9}\,.\,a\text{ very nearly;}$$

so, if $a^3=N+D$, then

$$N^{\frac{1}{3}}=\frac{3N(9a^3-2D)^2+D^2(6a^3+5D)}{3N(18a^3-D)^2+144D^2a^3-D^3}\,.\,4a\text{ nearly.} \quad . \quad . \quad . \quad . \quad . \quad . \quad (C)$$

To find $\sqrt[3]{29}$, take $a=3$; then $D=a^3-N$, $\therefore$ here $=-2$; and then our last formula gives

$$29^{\frac{1}{3}}=\frac{87(247)^2+4(152)}{87(488)^2+144\times4\times27+8}\,.\,12=3{\cdot}0723168,$$

which is correct to its last decimal figure 8.

Easy Demonstration of Dr. Hutton's elegant formula for approximating to $N^{\frac{1}{n}}$, with an important Remark or Estimate of the degree of accuracy attained by means of its use and application.

Let a be the assumed near value of $N^{\frac{1}{n}}$, whose exact value is $=a+x$; then, as N must

$$=(a+x)^n=a^n+na^{n-1}x+\frac{n(n-1)}{2}a^{n-2}x^2+\frac{n(n-1)(n-2)}{2\,.\,3}a^{n-3}x^3\ \&c.,$$

$$\therefore\ x=\frac{N-a^n}{na^{n-1}+\frac{n\,.\,n-1}{2}a^{n-2}x+\ \&c.};$$

and as x is very small, therefore it is nearly $=\frac{N-a^n}{na^{n-1}}$. By substituting this value for the first power of x in the preceding denominator and omitting the subsequent terms therein containing x^2, x^3, &c., we now find, *more nearly*,

$$\frac{x}{a}=\frac{2(N-a^n)}{2na^n+(n-1)(N-a^n)}=\frac{2(N-a^n)}{(n-1)\,N+(n+1)a^n},$$

and thus the corrected root $a+x=a\left(1+\frac{x}{a}\right)$ comes out

$$=a\left(1+\frac{2(N-a^n)}{(n-1)N+(n+1)a^n}\right)=\frac{(n+1)N+(n-1)a^n}{(n-1)N+(n+1)a^n}\times a, \quad . \quad . \quad (D)$$

which is the elegant formula of Dr. Hutton, first given in his Fourth Tract in the year A.D. 1786.

Now, to estimate the degree of accuracy attained by each new application of this elegant formula, let $N=a^n$, so that a is the correct nth root of N, and $a+x$ the assumed or guessed root whose error is x; then the rule being applied, gives the corrected root

$$=\frac{(n+1)a^n+(n-1)(a+x)^n}{(n-1)a^n+(n+1)(a+x)^n}\times\left(1+\frac{x}{a}\right)a=\frac{(n+1)\left(1+\frac{x}{a}\right)+(n-1)\left(1+\frac{x}{a}\right)^{n+1}}{n-1+(n+1)\left(1+\frac{x}{a}\right)^n}\times a$$

$$=a\left(1+\frac{n^2-1}{12}\cdot\frac{x^3}{a^3}\right) \text{ nearly.}$$

Now if the first two or three figures to the left be correct in $a+x$ then the relative error $\frac{x}{a}$ will be $<\frac{1}{100}$, and $\therefore \frac{x^3}{a^3}<\frac{1}{1000000}$; and as $\frac{n^2-1}{12}$ is in general small when n is not a large integer (it is <1 when $n=2$ or 3), $\therefore$ the new corrected root will be true in its first six figures (to the left); and if the assumed root $a+x$ agree with the true root a in its first three or four figures to the left, then its relative error $\frac{x}{a}$ must plainly be $<\frac{1}{1000}$, and therefore the relative error $\frac{n^2-1}{12}\cdot\frac{x^3}{a^3}$ of the corrected root will be $<\frac{a}{1000000000}$ when $n<10$; so that its first nine figures at the left-hand side must be correct; and hence, in general, each operation or new application of this formula trebles the number of correct figures in the assumed root.

On the Evaluation in Series of certain Definite Integrals. By J. W. L. Glaisher, *B.A., F.R.A.S.*

It is a well-known result (due originally to Laplace) that

$$\int_0^\infty e^{-v^2-\frac{\alpha^2}{v^2}}\,dv=\frac{\sqrt{\pi}}{2}e^{-2\alpha};$$

so that by continued operation with the symbol $\frac{1}{\alpha}\frac{d}{d\alpha}$ or its reciprocal, the value can be found of $\int_0^\infty v^{\pm 2i}e^{-v^2-\frac{\alpha^2}{v^2}}dv$. The result is

$$\int_0^\infty v^{2i}e^{-v^2-\frac{\alpha^2}{v^2}}dv=\alpha^n\int_0^\infty v^{-2i-2}e^{-v^2-\frac{\alpha^2}{v^2}}dv$$

$$=\frac{1.3\ldots(n-2)}{2^{\frac{1}{2}(n+1)}}\sqrt{\pi}\left\{1+\frac{n-1}{n-1}2\alpha+\frac{(n-1)(n-3)}{(n-1)(n-2)}\frac{(2\alpha)^2}{2}+\ldots\right\}e^{-2\alpha}\quad . \quad . \quad . \quad . \quad (1)$$

in which n is written for $2i+1$ (so that $2i=n-1$); the series is to terminate when the factor zero appears first in the numerator of a term. There are several ways in which (1) can be proved; but it is unnecessary to enter into details, as it is only a case of a more general formula proved below. The identity of the two integrals in (1) is obvious, since each is deducible from the other by taking $u=\frac{\alpha}{v}$.

But although (1) gives the value of $\int_0^\infty v^{n-1}e^{-v^2-\frac{\alpha^2}{v^2}}dv$ when $n-1$ is of the

form $\pm 2i$, it gives no indication of its value when n is not a positive or negative odd integer; and it will be found that the two most natural methods of evaluating this integral, viz. by expanding the factor $e^{-\frac{a^2}{v^2}}$ and integrating term by term, or by multiplying by e^{2a} and transforming the new integral, &c., both fail through the occurrence of infinite values for the terms after a certain point, the reason for which will appear further on. It might perhaps be thought that when n was arbitrary the formula (1), the factorial being replaced by the Gamma-function, would still be true by the principle of the permanence of equivalent forms, the series then extending to infinity; but such is not the case. The value of the integral in the general case may be found as follows, the steps of the method only being indicated in this abstract.

It is found that Riccati's equation $\frac{d^2u}{dx^2}-x^{2q-2}u=0$ is satisfied by the integral $\int_0^\infty e^{-u}dz$, u being written for $z^{2q}+\frac{x^{2q}}{4q^2z^{2q}}$*, and also by certain series given in the 'Philosophical Magazine,' ser. 4, vol. xxxvi. p. 348. As the differential equation is linear, it follows that the integral must be of the form A × one series + B × the other series, A and B being constants. Transforming every thing now by assuming $n=\frac{1}{q}$, $a=\frac{x^q}{2q}$, it will be found that, after very considerable reductions, we have the result that if

$$U=1-\frac{2a^2}{n-2}+\frac{(2a^2)^2}{(n-2)(n-4).1.2}-\dots$$

and

$$V=1+\frac{2a^2}{n+2}+\frac{(2a^2)^2}{(n+2)(n+4).1.2}-\dots,$$

then

$$\int_0^\infty v^{n-1}e^{-v^2-\frac{a^2}{v^2}}dv=AU+Ba^nV. \quad \dots\dots \quad (2)$$

[The details of the transformation indicated above are, to a great extent, given in the 'Philosophical Magazine,' for June 1872 (vol. xliii. p. 433 &c.). The original series are given at the top of page 434, and their transformations (taking $\frac{x^q}{q}=\beta$) at the bottom of the same page, while U and V are merely (2) and (3) of page 435, $2a$ being written for β, as is done throughout. The following errata should be noticed in the formulæ as they stand in the 'Philosophical Magazine,' viz. the factor β^n is accidentally omitted from the values of R and S given at the foot of page 434, and the factor 2 is omitted in the denominators of the second term in (2) and (3) $\left(\text{it should be } \frac{\beta^2}{2(n\pm 2)}\right)$; also in (2) β^1 should be β^n. None of these slips affect the subsequent work, for they are treated as if in their correct forms, not as printed.]

Resuming (2), it remains to determine A and B. By putting $a=0$, we obtain at once $A=\frac{1}{2}\Gamma\left(\frac{n}{2}\right)$. Let $B=\phi(n)$, and transform (2) by taking $\frac{a}{v}$ for v; we thus find

$$\int_0^\infty v^{-n+1}e^{-v^2-\frac{a^2}{v^2}}dv=\tfrac{1}{2}\Gamma\left(\frac{n}{2}\right)a^{-n}U+\phi(n)V. \quad \dots\dots \quad (3)$$

But this integral is the same as the integral in (2), with the sign of n changed; therefore, observing that a change of sign in n turns U into V, and *vice versâ*, we see that the right-hand side of (3) also

* Quarterly Journal of Pure and Applied Mathematics, vol. xi. p. 267.

$$=\tfrac{1}{2}\Gamma\left(-\frac{n}{2}\right)\mathrm{V}+\phi(-n)\,a^{-n}\mathrm{U};$$

whence it follows that

$$\phi(n)=\tfrac{1}{2}\Gamma\left(-\frac{n}{2}\right),$$

and

$$\int_0^\infty v^{n-1}e^{-v^2-\frac{a^2}{v^2}}dv=\tfrac{1}{2}\cdot\left\{\Gamma\left(\frac{n}{2}\right)\mathrm{U}+a^n\Gamma\left(-\frac{n}{2}\right)\mathrm{V}\right\}, \quad . \quad . \quad . \quad . \quad (4)$$

the formula in question.

When $n=2i+1$, it will be found that this gives, after use of the formula $\Gamma(m)\,\Gamma(1-m)=\frac{\pi}{\sin m\pi}$ and reduction, as the value of the integral

$$\tfrac{1}{2}\Gamma\left(\frac{n}{2}\right)\left\{\mathrm{U}-\frac{(-)^i 2^n a^n n}{(1.3\ldots n)^2}\mathrm{V}\right\},$$

which, by means of the formulæ in the Number of the 'Philosophical Magazine' last quoted, is readily identified with (1).

The form of (4) affords the reason why the usual methods fail to give the value of the integral, as it shows that the result is not generally expansible in integer powers of a. Generally, therefore,

$$\int_0^\infty v^{n-1}e^{-v^2-\frac{a^2}{v^2}}dv=\tfrac{1}{2}\Gamma\left(\frac{n}{2}\right)\left\{1+\frac{n-1}{n-1}2a+\ldots\right\}e^{-2a}+\tfrac{1}{2}\Gamma\left(-\frac{n}{2}\right)a^n\left\{1+\frac{n+1}{n+1}2a+\ldots\right\}e^{-2a}$$

But when n is a positive or negative odd integer, it is enough to take only the terminating series, and ignore the other altogether; a more complete explanation of the reason for this than is given here can be gathered from the paper in the 'Philosophical Magazine.' If n = a positive or negative even integer, the series for U or V becomes infinite, and then one of the series involves $\log a$ as a factor (see Euler, Calc. Integ. vol. ii. chap. vii.). Even the partial discussion of this case must be omitted in this abstract.

On the Function that stands in the same Relation to Bernoulli's Numbers that the Gamma-function does to Factorials. *By* J. W. L. Glaisher, *B.A., F.R.A.S.*

It is always a matter of some interest to regard a series of constants as particular values of a continuous function, which function can usually be exhibited as a definite integral. The problem is of course indeterminate, as through a series of points at finite intervals from one another an infinite number of curves can be drawn; but, as in the case of the Gamma-function in its connexion with the factorial $1.2\ldots x$, there is usually but one curve, which, in an analytical point of view, stands in this relation. It seems, therefore, worth while to investigate the function connecting Bernoulli's numbers; and this is readily effected as follows.

Denoting by B_n the nth Bernoulli's number, we have

$$\mathrm{B}_n=\frac{2(1.2.3\ldots2n)}{(2\pi)^{2n}}\left\{1+\frac{1}{2^{2n}}+\frac{1}{3^{2n}}+\ldots\right\}$$

$$=4n\int_0^\infty t^{2n-1}\left(e^{-2\pi t}+e^{-4\pi t}+\ldots\right)dt$$

$$=4n\int_0^\infty\frac{t^{2n-1}\,dt}{e^{2\pi t}-1},$$

the expression in question, which gives a value for B_n when n is fractional. In all cases, therefore, the formula is

$$B_n=\frac{2\Gamma(2n+1)}{(2\pi)^{2n}}\left\{1+\frac{1}{2^{2n}}+\frac{1}{3^{2n}}+\dots\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

The first four Bernoulli's numbers are $\frac{1}{6}$, $\frac{1}{30}$, $\frac{1}{42}$, $\frac{1}{30}$, after which they increase rapidly, so that there is a minimum between B_2 and B_4. As this minimum point is the only intrinsic point of interest on the curve $y=B_x$, the following Table was calculated of values of B_x in its vicinity:—

x.	B_x.	x.	B_x.
2·0	0·0333333	3·0	0·0238095
2·1	0·0309658	3·1	0·0239930
2·2	0·0290652	3·2	0·0243304
2·3	0·0275461	3·3	0·0248228
2·4	0·0263448	3·4	0·0254741
2·5	0·0254132	3·5	0·0262913
2·6	0·0247149	3·6	0·0272845
2·7	0·0242228	3·7	0·0284668
2·8	0·0239167	3·8	0·0298548
2·9	0·0237822	3·9	0·0314688
		4·0	0·0333333

From Lagrange's formula, that if A, B, C be three values corresponding to arguments a, b, c, then

$$X=A\frac{(x-b)(x-c)}{(a-b)(a-c)}+B\frac{(x-c)(x-a)}{(b-c)(b-a)}+C\frac{(x-a)(x-b)}{(c-a)(c-b)},$$

it follows that if A, B, C are three values in the neighbourhood of the minimum, then x, the argument of the minimum,

$$=\frac{(b^2-c^2)A+(c^2-a^2)B+(a^2-b^2)C}{(b-c)A+(c-a)B+(a-b)C};$$

and by deducing the value of x from 2·8, 2·9, and 3·0, and also from 2·9, 3·0, and 3·1, it is found that the minimum corresponds to $x=2·93\dots$; and therefore, by the usual interpolation-formula, the minimum value $=·02377\dots.$

The values in the Table were calculated from the formula (1) expressed in the modified form

$$B_x=\frac{2\Gamma(2x+1)}{(2\pi)^{2x}}\cdot\frac{1}{1-\frac{1}{2^{2x}}}\left(1+\frac{1}{3^{2x}}+\frac{1}{5^{2x}}+\dots\right).$$

For $x=2·1$ it was necessary to include terms as far as $\left(\frac{1}{49}\right)^{2x}$, for 2·2 as far as $\left(\frac{1}{35}\right)^{2x}$, and ultimately for $x=4$ only as far as $\left(\frac{1}{7}\right)^{2x}$. The calculation was performed in duplicate, and the accuracy of the values is apparent on forming the 5th differences. The values of $\log\Gamma(x)$ were deduced from Legendre's Tables.

It may be noted that, by means of the formula

$$\frac{1}{\left(1-\frac{1}{2^n}\right)\left(1-\frac{1}{3^n}\right)\left(1-\frac{1}{5^n}\right)\dots}=1+\frac{1}{2^n}+\frac{1}{3^n}+\frac{1}{4^n},$$

somewhat different form may be obtained for B_n; for we have

$$B_n=\frac{2\Gamma(2n+1)}{(2\pi)^{2n}}\frac{2^{2n}.3^{2n}\dots}{(2^{2n}-1)(3^{2n}-1)\dots},$$

and

$$\frac{\pi^2}{6} = \frac{2^2 . 3^2 \ldots}{(2^2-1)(3^2-1)\ldots};$$

so that

$$B_n = \frac{2\Gamma(2n+1)}{(24)^n} \frac{(2^2-1)^n(3^2-1)^n(5^2-1)^n\ldots}{(2^{2n}-1)(3^{2n}-1)(5^{2n}-1)\ldots},$$

2, 3, 5,.... being the series of prime numbers.

On the Law of Distribution of Prime Numbers.
By J. W. L. Glaisher, *B.A., F.R.A.S.*

In the 'Philosophical Magazine' for July 1849 the late Mr. Hargreave proved two results of great interest in the theory of numbers, viz. that the average distance between two primes about the point x of the ordinal series was $\log_e x$, and that the number of primes between x' and x was very nearly $\mathrm{li}\, x' - \mathrm{li}\, x$, $\mathrm{li}\, x$ being the logarithm-integral of x, viz. $\mathrm{li}\, x = \int_0 \frac{dx}{\log x}$. A result practically the same was also arrived at by Tchebycheff, Petersburgh Transactions, 1848 (see 'Philosophical Magazine,' August 1851).

The general truth of these results was verified by Hargreave for a number of ranges among numbers less than a million; but in only one case did he compare the numbers given by the formulæ with the numbers counted above this limit. The means for making this comparison are afforded by Burckhardt's Tables, which give the least divisor of every number not divisible by 2, 3, or 5 from unity to three millions, and Dase's Tables, which do the same for numbers between six millions and nine millions. The intermediate three millions, although existing in manuscript in the library of the Berlin Academy, have not been published. Burckhardt's Tables were published in 1814–17, and were therefore accessible to Hargreave; but Dase's have only been published since 1862. By means of these Tables, of course all the primes included within their limits can be found, as their "least factors" being themselves, they are denoted in the Tables by a bar. I have therefore had all the primes in every hundred of the six millions over which the Tables extend counted, and have also calculated the numbers given by the formulæ; and the results, arranged in groups of 50,000 for two millions (viz. the second and the ninth), are given in the two Tables below. The second million was chosen in preference to the first for insertion in this abstract, partly because results derived from the counting of primes in the latter have been exhibited by Legendre, Hargreave, and others, and partly because the distribution is very anomalous near the commencement of the series of numerals.

The numbers in the millions were divided into groups of 50,000, and x' is written for brevity for $x+50{,}000$. In the first Table the numbers in the "Primes counted" column are the numbers of primes between x and x'; thus there are 3635 primes between 1,000,000 and 1,050,000, &c. In the second Table the logarithm of the middle number of the group of the 50,000 was taken as the logarithm for the group, and the "Average interval between the primes" was found by dividing 50,000 by the corresponding number in the "Primes counted" column of the first Table, the average intervals between two primes in the group from 1,000,000 to 1,050,000 being 13·76, &c.

The logarithm-integral is only a transformation of the exponential integral, the relation between the two being $\mathrm{li}\, e^x = \mathrm{Ei}\, x$; and by the use of Taylor's theorem we find

$$\mathrm{Ei}(x+h) - \mathrm{Ei}\, x = h\frac{e^x}{x} + \frac{h^2}{1.2}\left(\frac{e^x}{x} - \frac{e^x}{x^2}\right) + \frac{h^3}{1.2.3}\left(\frac{e^x}{x} - 2\frac{e^x}{x^2} + \frac{2e^x}{x^3}\right) + \ldots$$

$$= (e^h - 1)\frac{e^x}{x} - \frac{h^2}{2}\frac{e^x}{x^2} - \frac{h^3}{3}\frac{e^x}{x^3} + \ldots,$$

x.	$\mathrm{li}\,x' - \mathrm{li}\,x$.	Primes counted.	Difference.	x.	$\mathrm{li}\,x' - \mathrm{li}\,x$.	Primes counted.	Difference.
1,000,000	3613	3635	−22	8,000,000	3145	3121	+24
1,050,000	3600	3580	+20	8,050,000	3144	3129	+15
1,100,000	3589	3589		8,100,000	3143	3127	+16
1,150,000	3577	3636	−59	8,150,000	3141	3174	−33
1,200,000	3567	3530	+37	8,200,000	3140	3161	−21
1,250,000	3557	3551	+ 6	8,250,000	3139	3122	+17
1,300,000	3547	3522	+25	8,300,000	3138	3171	−33
1,350,000	3538	3579	−41	8,350,000	3137	3114	+23
1,400,000	3529	3501	+28	8,400,000	3135	3092	+43
1,450,000	3520	3526	− 6	8,450,000	3134	3153	−19
1,500,000	3512	3508	+ 4	8,500,000	3133	3160	−27
1,550,000	3504	3465	+39	8,550,000	3132	3163	−31
1,600,000	3496	3498	− 2	8,600,000	3131	3129	+ 2
1,650,000	3489	3507	−18	8,650,000	3130	3152	−22
1,700,000	3482	3468	+14	8,700,000	3129	3139	−10
1,750,000	3475	3465	+10	8,750,000	3127	3160	−33
1,800,000	3468	3470	− 2	8,800,000	3126	3108	+18
1,850,000	3462	3487	−25	8,850,000	3125	3112	+13
1,900,000	3455	3473	−18	8,900,000	3124	3135	−11
1,950,000	3449	3430	+19	8,950,000	3123	3135	−12
Total	70429	70420	+ 9	Total ...	62676	62760	−84

x.	$\log \frac{x+x'}{2}$.	Average interval between two consecutive primes.	x.	$\log \frac{x+x'}{2}$.	Average interval between two consecutive primes.
1,000,000	13·84	13·76	8,000,000	15·90	16·02
1,050,000	13·89	13·97	8,050,000	15·90	15·98
1,100,000	13·93	13·93	8,100,000	15·91	15·99
1,150,000	13·98	13·75	8,150,000	15·92	15·75
1,200,000	14·02	14·16	8,200,000	15·92	15·82
1,250,000	14·06	14·08	8,250,000	15·93	16·02
1,300,000	14·10	14·20	8,300,000	15·93	15·77
1,350,000	14·13	13·97	8,350,000	15·94	16·06
1,400,000	14·17	14·28	8,400,000	15·95	16·17
1,450,000	14·20	14·18	8,450,000	15·95	15·86
1,500,000	14·24	14·25	8,500,000	15·96	15·82
1,550,000	14·27	14·43	8,550,000	15·96	15·79
1,600,000	14·30	14·29	8,600,000	15·97	15·98
1,650,000	14·33	14·26	8,650,000	15·98	15·86
1,700,000	14·36	14·42	8,700,000	15·98	15·93
1,750,000	14·39	14·43	8,750,000	15·99	15·82
1,800,000	14·42	14·41	8,800,000	15·99	16·09
1,850,000	14·44	14·34	8,850,000	16·00	16·07
1,900,000	14·47	14·40	8,900,000	16·00	15·95
1,950,000	14·50	14·58	8,950,000	16·01	15·95

collecting together all the coefficients of $\frac{e^x}{x}$,

$$=\frac{e^{x+h}-e^x}{x}-\frac{h^2e^x}{2x^2}-\frac{h^3}{3}\frac{e^x}{x^2}+\ldots;$$

and therefore

$$\mathrm{li}\,(y+h)-\mathrm{li}\,y=\frac{h}{\log_e y}-\frac{y}{2}\left\{\frac{\log_e\left(1+\frac{h}{y}\right)}{\log_e y}\right\}^2-\frac{y}{3}\frac{\left\{\log_e\left(1+\frac{h}{y}\right)\right\}^3}{(\log_e y)^2}+\ldots,$$

an extremely convenient formula for calculating from Hargreave's principles the approximate number of primes between limits. The last-written formula was, of course, deduced from the previous one by taking $e^x=y$ and $e^{x+h}=y+h$. In the Tables $h=50,000$, and for $y=1,000,000$ the value of the second term only amounted to 6·2, and the third 0·2; for $y=1,950,000$ the second term was 3·2, and the third insensible, while for $y=8,000,000$ the second term was only 0·6; so that the first two terms were practically sufficient for the second million, with the interval of 50,000, and the first alone for the ninth million. It is impossible, in a brief abstract like the present, to notice the agreement with Legendre's formula $\frac{x}{\log x-1\cdot08366}$ &c.; but the author hopes to publish the values for the other millions elsewhere.

The results given in the two Tables above were calculated or counted in duplicate throughout; and it is believed that none of the values of $\mathrm{li}\,x'-\mathrm{li}\,x$ will be found wrong by so much as a unit, though an error of this amount is just possible. In the total, which was formed merely by adding the numbers in the $\mathrm{li}\,x'-\mathrm{li}\,x$ column, of course a somewhat greater error is possible by accumulation. It may be convenient here to state that li (1,000,000) = Ei (13·81551) = 78627·2 . .; li (1,050,000) = Ei (13·86430) = 82239·9. . . . ; li (1,100,000) = Ei (13·91082) = 85840·2. . . . ; li (1,150,000) = Ei (13·95527) = 89428·7. . . . These values were not obtained from the first by means of the above Table, but were each calculated independently from the semiconvergent series

$$\mathrm{Ei}\,x=e^x\left\{\frac{1}{x}+\frac{1}{x^2}+\frac{1\,.\,2}{x^3}+\frac{1\,.\,2\,.\,3}{x^4}+\frac{1\,.\,2\,.\,3\,.\,4}{x^5}+\ldots\right\}.$$

Hargreave has given a formula which is no doubt a particular case of that in this paper (though I have not yet compared them); but either some of his constants must have been erroneous, or he must have made errors of calculation, as all the numbers given in the Table on page 48 of the 'Philosophical Magazine' for July 1849, which was calculated by means of ✠, seem to be more or less inaccurate (see 'Philosophical Transactions,' 1870, p. 386; the arguments are identical, as, in fact, Hargreave has taken integer arguments of the exponential integral, viz. Ei 1, Ei 2, &c.).

It may be added that the number of primes between 1,000,000 and 2,000,000 was computed by Hargreave and found to be 70,430, which differs by only a unit from the value in this paper (which value, as before remarked, could very well have been inaccurate by even more than this amount); and this completely verifies the accuracy of the numbers in the $\mathrm{li}\,x'-\mathrm{li}\,x$ column of the first Table between two and three millions. Hargreave (Philosophical Magazine, August 1851) found the number of "Primes counted" up to one million and between two and three millions to be 78,493 and 67,751 respectively; while the formula gave 78,626 and 67,916, the discrepancies being much greater than that which is here found for the second million, where the difference was only 9. The numbers I have found for the "Primes counted" differ from Hargreave's; but as they have as yet been counted but once, no great reliance can be placed on them. The formula values I have not yet calculated.

On a Verification of the Probability Function.
By J. E. Hilgard, *U. S. Coast Survey.*

On Tridiametral Quartan Curves. *By* F. W. NEWMAN.

PROBLEM. To find the conditions that a Quartan may have 3 Diameters.

That it may have one, the equation must admit the form

$$ay^4 + X_2 y^2 = X_4,$$

where X_n means a function of x of the nth degree.

Let $r^2 = x^2 + y^2$; then we may write

$$ar^4 + (Ax^2 + Bx + C)r^2 = kx^4 + lx^3 + mx^2 + nx + p.$$

This *form* will not be changed if we change the origin to any point in the axis of y; hence, if there be a second diameter, we may may suppose it to pass through the origin, which we treat as a Pole, making $x = r\cos\psi$, $y = r\sin\psi$.

Then $ar^4 + (Ar^2\cos^2\psi + Br\cos\psi + C)r^2 =$

$$kr^4\cos^4\psi + lr^3\cos^3\psi + mr^2\cos^2\psi + nr\cos\psi + p = 0,$$

which by the routine of trigonometry is expressible as

$$\begin{aligned}&\{a - \tfrac{3}{8}k + \tfrac{1}{2}(A-k)\cos 2\psi - \tfrac{1}{8}k\cos 4\psi\}r^4\\ &+ \{(B - \tfrac{3}{4}l)\cos\psi - \tfrac{1}{4}l\cos 3\psi\}r^3\\ &+ \{(C - \tfrac{1}{2}m) - \tfrac{1}{2}m\cos 2\psi\}r^2 = nr\cos\psi + p.\end{aligned}$$

This is the equation of every Quartan which has so much as one diameter.

In order that the line expressed by $\psi = \gamma$ may be a new diameter, it is necessary and it suffices that the same equation should result by substituting $\psi = \gamma + \omega$, and $\psi = \gamma - \omega$, where γ is a definite constant, r, ω the variables of the equation. Put $\psi = \gamma \pm \omega$; then in order that $\pm$ may give the same result, the terms concerned must vanish in the coefficients of r^4, r^3. r^2, r separately. It must be observed that the assumption $\gamma = 0$ or $\gamma = 180°$ is useless; and $\gamma = 90°$ leads us to two rectangular diameters, not to three. Hence we must avoid to suppose $\sin\gamma = 0$ or $\sin 2\gamma = 0$.

Now (1) $nr\sin\gamma \,.\, \sin\omega = 0$, $\therefore n = 0$;

(2) $m\sin 2\gamma\sin 2\omega = 0$, $\therefore m = 0$;

(3) in the coefficient of r^3, we need at once

$$(B - \tfrac{3}{4}l)\sin\gamma\sin\omega = 0;\quad \tfrac{1}{4}l\sin 3\gamma \,.\, \sin 3\omega = 0.$$

It is useless to suppose $l = 0$, $B = 0$; for this, joined with $m = 0$, $n = 0$, reduces the equation to the Doubly Diametral. Hence our only useful results are

$$\sin 3\gamma = 0,\ B = \tfrac{3}{4}l;\ \text{which leave B and } l \text{ finite.}$$

(4) $(A - k)\sin 2\gamma \,.\, \sin 2\omega = 0$, $k\sin 4\gamma\sin 4\omega = 0$.

We cannot make $\sin 4\gamma = 0$, since we already require $\sin 3\gamma = 0$. Hence nothing remains but $k = 0$, $A = 0$.

Thus the original equation is reduced to

$$ar^4 + (Bx + C)r^2 = \tfrac{4}{3}Bx^3 + p; \quad \dots \dots \dots \quad (h)$$

and from $\sin 3\gamma = 0$ we get *two* new diameters, defined by $\gamma = 60°$ and $\gamma = 180°$. Thus the problem is solved.

Originally, the assumption $a = 0$ would have left our monodiametral curve still a Quartan. But after supposing $A = 0$ and $k = 0$, we cannot make a also $= 0$ without reducing the equation to a Tertian. In fact it is easy to show that the conditions here investigated yield the known Tertian *Trijuga* when we add the assumption $a = 0$.

Writing $x = r\cos\psi$, $4x^3 = r^3(\cos 3\psi + 3\cos\psi)$, we find

$$ar^4 + Cr^2 = \tfrac{1}{3}Br^3\cos 3\psi + p, \quad \dots \dots \dots \quad (i)$$

which is the most general Polar Equation of Tridiametral Quartans.

Again, solving (h) for r^2, and making $a = 1$, since a must be finite,

$$r^2 + \tfrac{1}{2}(Bx + C) = \surd\{\tfrac{4}{3}Bx^3 + \tfrac{1}{4}(Bx + C)^2 + p\}.$$

Thus the general equation to rect. coords. has the form

$$y^2 + x^2 + B'x + C' = \surd\{\tfrac{8}{3}B'x^3 + (B'x + C')^2 + E\}, \quad \dots \dots \quad (j)$$

which has 3 Parameters.

If, however, $C'=0$ and $E=0$, the Polar equation becomes simply $r=\frac{2}{3}B'\cos 3\psi$, which is a Starry Trijuga, admitting $r=0$.

In general, the equation to rect. coords. falls under the class

$$y^2+X_2=\sqrt{X_3},$$

which is the highest form of those which I call *Quartotertian*.

The Polar equation may be presented in the form $\cos 3\psi=\frac{Ar^4+Br^2+C}{r^3}$. .

The curve is evidently in every case finite, and the species must apparently change according as the equation admits the forms $ar^3\cos 3\psi=(r^2-b^2)(r^2-c^2)$, $ar^3\cos 3\psi=(r^2+b^2)(r^2-c^2)$, $ar^3\cos 3\psi=(r^2+b^2)(r^2+c^2)$, or finally $ar^3\cos 3\psi=(r^2\pm b^2)^2+c^4$. Evidently $\frac{dr}{dx}=0$, when $\sin 3\psi=0$.

If $\psi=120^\circ+\theta$, $\cos 3\psi=\cos 3\theta$. Hence the figure is Equilateral.

On Quartan Curves with 3 or 4 Diameters. By F. W. Newman.

This Memoir proposes and solves the Problems, in what case Curves of the Fourth Degree have 3 or 4 diameters.

It briefly analyzes the forms of the Tridiametral Curves, under the heads which rise out of the general equation

$$2ar^3\cos 3\psi=r^4+2br^2+c=R:$$

1. when $R=r^4$, or $2a\cos 3\psi=r$;
2. when $R=r^4-\beta^2r^2$, or $2ar\cos 3\psi=r^2-\beta^2$;
3. when $R=r^4\beta^2r^2$;
4. when $R=r^4-\gamma^4$;
5. when $R=r^4+\gamma^4$, and generally when R is essentially positive;
6. when $R=(r^2-\beta^2)(r^2-\gamma^2)$, which has 3 remarkable forms;
7. when $R=(r^2+\beta^2)(r^2-\gamma^2)$, which has 2 forms, according as β^2 is $>\gamma^2$ or $<\gamma^2$.

On Monodiametral Quartan Curves. By F. W. Newman.

This Memoir is a continuation of the paper laid before the Association last year on Doubly Diametral Quartan Curves, and follows upon a notice now presented on Tridiametrals and Quadridiametrals of the same degree.

Employing X_n to mean an integer function of x, of degree n, it is proposed to digest all the Monodiametral curves into five Groups, twenty-one Classes, as follows:—

I.
1. $y^4+2Ay^2=X_1$, or x an integer function of y^2 [*Quartic* Parabolas].
2. $y^4+X_1y^2=X_1$, or x rational in y^2 (Conic Parabola for asymptotes).

II. (In these, y^2 is rational in x.)
3. $X_2y^2=X_1$ }
4. $X_2y^2=X_2$ } (Horizontal and Vertical asymptotes).
5. $y^2=X_4$ (two equal and opposite Conic Parabolas for asymptotes).
6. $xy^2=X_4$; or, the Semicubical; with *Tertian* asymptote.
7. $X_2y^2=X_3$ (Conic Parabola for asymptote).
8. $X_2y^2=X_4$; Quartohyperbolic.

III.
9. $y^2=\sqrt{X_3}$; Quartotertian of 1st Branch.
10. $y^2\pm A^2=\sqrt{X_3}$; Quartotertian of 2nd Branch.
11. $y^2+X_1=\sqrt{X_1}$ (Epiparabolic asymptote).
12. $y^2+X_1=\sqrt{X_2}$ (Unequal Conic Parabolas for asymptotes). [$y^2=\sqrt{X_2}$ is omitted as Doubly Diametral.]
13. $y^2+X_1=\sqrt{X_3}$; Quartotertian of 3rd Branch (*Epi*parabolic asymptote).

IV.
14. $y^2+X_2=\sqrt{X_1}$ (*Epi*hyperbolic asymptote).
15. $y^2+X_2=\sqrt{X_2}$ (admits two asymptotic hyperbolas, with their rectilinear asymptotes *parallel*, set to set).
16. $y^2+X_2=\sqrt{X_3}$; Quartotertian of 4th Branch. (*Tridiametrals* must be excluded.) Epihyperbolic asymptotes.

V. $\begin{cases} \text{17. } y^2=\sqrt{X_4} \text{ (Quartohyperbolic Group).} \\ \text{18. } y^2\pm A^2=\sqrt{X_4}. \\ \text{19. } y^2\mp X_1=\sqrt{X_4} \text{ (one Hyperbolic asymptote at most).} \\ \text{20. } y^4+X_2y^2=X_3 \text{ or } X_2 \text{ or } X_1 \text{ (perhaps one Parabolic and one Hyperbolic asymptote).} \\ \text{21. } y^4+X_2y^2=X_1 \text{ or } y^2+X_2=\sqrt{X'_4} \text{ (perhaps two Hyperbolic asymptotes, all differently directed).} \end{cases}$

The mode of analysis used in the most difficult cases is as follows:—

It is assumed that if $\phi\ (v\ x)=0$, and $f\ (u\ x)=0$ are known curves, and $y'^2=v^2+u^2$, $y''^2=v^2-u^2$, the curve F $(y,\ x)=0$ can thence be traced, y'^2 and y''^2 being the two positive roots of y^2, when such are real. Practically it is not difficult to decide on the course of $(y\ x)$, if the constants which enter the two auxiliaries are fixed: but the number of hypotheses concerning the relations of the constants in ϕ to the constants in f are embarrassing.

Thus, to trace $(y,\ x)$ from the equation $y^2+X_2=\pm\sqrt{X_4}$, which is the largest case, we put $X_2=-y_1^2$, or else $X_2=+y_0^2$, according to the sign which X_2 may assume within different limits, and $Y^2=\sqrt{X_4}$. Then either $y^2=Y^2-y_0^2$, giving at most only one positive value to y^2; or $y^2=y_1^2\pm Y^2$, giving in some cases two positive values to y^2.

This assumes that we know not only y_1 and y_0, which define Conic curves, but also $Y^2=\sqrt{X_4}$. If X_4 degenerate, $Y^2=\sqrt{X_1}$ is a Quartic Parabola. $Y^2=\sqrt{X_2}$ is a *Doubly* Diametral Quartan, which is here assumed to be known; $Y^2=\sqrt{X_3}$ is the primary Quartotertian (9th Class of Quartans); $Y^2=\sqrt{X_4}$ is the primary Quartohyperbolic of the 17th class. Thus the 9th class becomes auxiliary to the 10th, 13th, and 16th; and the 17th is auxiliary to all which follow it. The 1st class (Quartic Parabola) is auxiliary to the 11th and 14th.

It is believed that in the 8th class alone there are in strictness as many as 260 species. This makes it impossible to undertake to draw them all, which multiply more and more in the higher classes, as the number of constants increase. Nevertheless many diagrams are laid before the Association, nearly exhausting the forms of the earlier classes. The Semicubical and the Quartotertian are notable as peculiarly novel and most remote from the Doubly Diametral.

Many of the forms might be conjectured beforehand from the Doubly Diametral by merely introducing inequality, as in place of two equal, two unequal ovals. Nevertheless there is much that could never be so conjectured, just as in the Doubly Diametral we could not conjecture the forms of the inferior classes from knowing the superior forms.

On the Circular Transformation of Mobius.
By Prof. H. J. Stephen Smith, *F.R.S.*

General Physics.

On Sympathy of Pendulums. *By* Professor P. G. Tait, *F.R.S.E.*

On Relations between the Gaseous, the Liquid, and the Solid States of Matter.
By Prof. James Thomson, *LL.D., Queen's College, Belfast.*

The object of this paper is to submit some new theoretical considerations which constitute a further development of one portion of the views offered, at last year's Meeting of the Association, by the author, in his paper entitled "Speculations on the Continuity of the Fluid State of Matter, and on Relations between the Gaseous, the Liquid, and the Solid States." He has now to make reference to the abstract

of that paper printed in the 'Transactions' for last year at page 30; and, in particular, to the diagram of three curves shown sketched in fig. 1 of that abstract.

In respect to these curves several essential features had been, at the time of last year's Meeting, clearly discerned, and were pointed out and reasoned on by the author in his paper then read. His attempt to sketch out the curves, however, in such a way as that they should be in agreement with the known conditions then taken into consideration, soon forced on his attention the question whether the two curves, one of which is that between gas and liquid, and the other is that between gas and solid, ought to be drawn crossing as represented here in fig. 1 *a*, or as in fig. 1 *b*; and his object at present is to give a demonstration, subsequently deve-

Fig. 1 *a*.

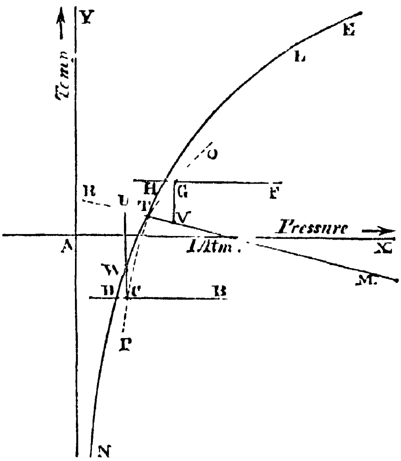
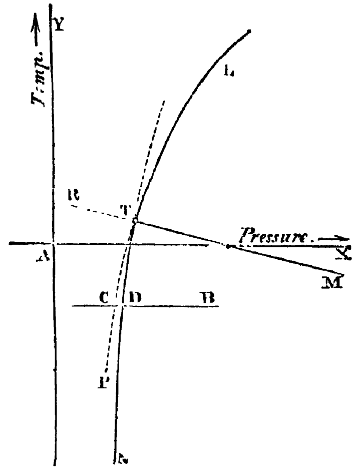


Fig. 1 *b*.



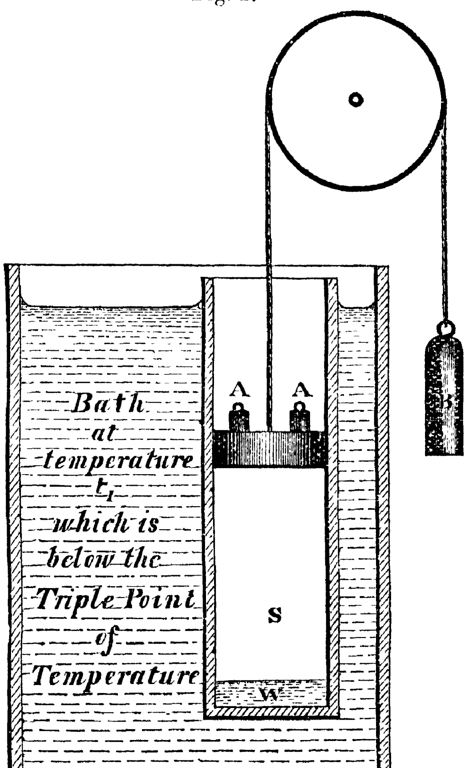
loped, showing that they must cross as in fig. 1 *a*; or, in other words, as in the diagram which he gave in the abstract of his last year's paper.

It is to be understood that A X and A Y are the axes of coordinates for pressures and temperatures respectively: A, the origin, being taken as the zero for pressures, and as the zero for temperatures on the Centigrade scale; and, for simplicity in expression and in thought, the diagram may be taken as relating to the particular substance of water, steam, and ice, rather than to substances in general. The curve E T P is the *boiling-line*, or the line which has its successive points such that for any one of them the two coordinates represent a pressure and temperature for a boiling-point, or a pressure and temperature which the water and steam can have when in mutual contact. It may also be called, for brevity, the *steam-with-water line*. In like manner the curve N T Q is the *steam-with-ice line*; and the curve M T R is the *water-with-ice line*. The full meaning of these diagrams may become more distinctly intelligible to the reader if he will advert to the explanations given in the paper already referred to in last year's 'Transactions,' as to fig. 1 in that paper,—explanations which, though now useful, need not be wholly repeated here, as the present paper is meant to be read in connexion with that previous one.

If we now look to fig. 1 *a* and suppose that we have water and steam in mutual contact, the pressure and temperature must be represented by the coordinates of some point of the steam-with-water curve L T P. Let us now suppose that we lower the temperature gradually while keeping water and steam in mutual contact: the point whose coordinates show the successively coexistent temperatures and pressures will pass downwards along the steam-with-water curve L T P. Let us suppose this operation continued so far as to bring this point into that part of the

curve which belongs to temperatures below that of the triple point T *. This supposed extension of the steam-with-water curve into temperatures below that of the triple point, where freezing would certainly set in if any ice were present, is to be conceived of as a curve corresponding to states of equilibrium between the steam and water. It is well known that water can, in various circumstances, be reduced in temperature below its freezing-point without its freezing; and this the author attributes to a difficulty of making a beginning of change of state †. It is also known that the presence of a gaseous atmosphere, of common air with aqueous vapour in contact with water, does not necessarily introduce any condition which will give liberty to the water-substance to make a beginning of change of state into ice, either from the liquid or the gaseous part, or from both at their face of contact. Thus there can scarcely be a doubt but that the steam-with-water curve, L T, has a practically attainable extension past T; and valid reasoning, the author thinks, may certainly be founded on the supposition of this curve as one of equilibrium between steam and water, whether or not, in various modes of experimenting, it might be easy or difficult or unmanageable to practically exclude all conditions which would give liberty to make a beginning of the formation of ice. We may then see that, supposing steam and water to be present together in a condition of temperature and pressure represented by any point such as C in fig. 1*a*, there is perfect freedom for the transition either way between water and steam. That is to say, while the water and steam are maintained at the temperature and pressure of the point C, the water is perfectly free to change to steam, and the steam is perfectly free to change to water. Let, for brevity, the temperature and pressure of the point C be denoted by t_1 and p_1 respectively.

Fig. 2.



Now, to aid our conception in a process of theoretical reasoning, let us imagine an apparatus possessing certain qualities in theoretic perfection, thus:—(see fig. 2).

Let there be a cylinder, standing upright, closed at bottom, open at top, and with a piston which works without leakage and without friction.

Let the weight of the piston, together with the atmospheric load on it, be balanced by a counterpoise B; or else let the whole apparatus be conceived to be enclosed in a large external vessel from which the air has been

* The meaning of the "Triple Point" is explained in the paper already referred to in last year's Transactions, page 32.

† In papers by the author (Proceedings of Royal Society, Nov. 24, 1859, page 158; and British Association Report, Transactions of Sections, 1859, page 25), the principle of attributing such phenomena to *a difficulty of making a beginning of change of state* was, so far as he is aware, first announced.

extracted, and then the counterpoise B must just balance the weight of the piston. Let weights A, A be laid on the piston, which will give exactly the pressure p_1 to the fluid enclosed in the cavity of the cylinder; and let this enclosed fluid be supposed to be water-substance taken at first in the state of steam with water, as shown in the figure, where S is steam and W is water.

Let the entire cylinder and its contents be maintained at the temperature t_1 (a temperature below that of the triple point) by immersion in a bath at that temperature, t_1, as shown in the figure.

Now apply an infinitely small extra weight on the piston, so that the internal pressure becomes $p_1+\delta$, where δ is infinitely small. This causes the steam to go perfectly gently down to water.

Now insert a particle of ice. Brisk action or agitation instantly sets in. Thus:—

(1) The water with ice cannot repose without both coming to the temperature which, for the pressure $p_1+\delta$, or we may here as well say for the pressure p_1, belongs to water with ice; that is to say, in reference to fig. 1 *a*, the water with ice cannot repose without both coming to the temperature of the point U on the water-with-ice line in that figure.

(2) The water at this raised temperature, or at any of the intermediate temperatures between this and the temperature t_1 of the surrounding bath, is in a state tending to ebullition into steam, a state in which boiling will ensue if a beginning be made at all, or if due facility to begin be afforded in any way.

(3) Conduction of heat, or conduction with convection, is briskly going on, conveying heat out to the bath, since the temperature inside is at some parts warmer than the bath, and is nowhere cooler.

Now, either ebullition ensues, or it does not.

First. Suppose it not to take place:—

Parts of the water are warmed by the freezing-process. They briskly transmit heat out to the bath, the freezing goes briskly on, and the same process of transmission of heat from a higher to a lower temperature goes briskly forward. This continues till all the enclosed fluid has become ice.

Now it is obvious that if there is a brisk action, with rapid conduction of heat, when steam, or water-substance partly steam and partly water, is allowed to pass into the state of ice while the pressure is $p_1+\delta$ and the surrounding temperature is t_1, there could be no return or reversal to the old condition of steam, or of steam with water, caused or allowed by merely an infinitely small abatement of pressure from $p_1+\delta$ to p_1. To cause the ice to evaporate, or to get it to remain in equilibrium with steam, which we know experimentally it can do at a low enough pressure, a finite (not infinitely small) abatement of pressure is necessary.

Thus has been proved what was wanted, provided we be right in supposing ebullition not to take place.

But now:—

Second. Suppose ebullition to ensue on the introduction of the ice—a complicated interaction of water, steam, and ice, involving brisk agitation, must set in. At any face of contact of water and ice, the temperature must be that of the point U in fig. 1 *a*; at any face of contact of steam and ice the temperature must become that which belongs to the pressure p_1 on the steam-with-ice line, and which is shown at the point W in fig. 1 *a* on the supposition of the curves crossing as represented in that figure; and at any face of contact of steam with water the temperature must be that of the point C. As yet we need not assume that we know whether the point W for pressure p_1 on the steam-with-ice line is at a higher temperature than that of C, as is represented in fig. 1 *a*, or at a lower temperature than that of C, as it would be if the curves crossed as in fig. 1 *b*; but clearly we know that the temperature of U is higher than that of C, which is the same as that of the bath; and we can also see that any steam in contact with water and surrounded with the bath at temperature t_1 while the pressure is p_1 will be ready to condense to water, or will actually so condense if the pressure be increased by the infinitely small augmentation δ, just as did the steam originally supposed to occupy part of the cavity. Thus we must have an action going briskly on, involving rapid conduction of heat, an action involving the

continual conversion of water-substance from the fluid state (gaseous or liquid) to ice, and which goes on till no steam remains to condense to water at a face of contact with water, and till no water remains to be frozen at a face of contact with ice. As this process goes on with briskness or agitation, involving rapid conduction of heat, we can see that, as in the previously supposed case, the process is irreversible by an infinitely small abatement of pressure; and we can see that to get steam to remain in repose in contact with ice at the temperature t_1 of the surrounding bath, we must have the pressure abated by a finite amount, so as to be decidedly less than the pressure p_1 belonging to steam with water at the fixed temperature of the bath: that is to say, for a temperature below the *triple point* the pressure of steam with ice is less than the pressure of steam with water.

Hence, referring to fig. 1 *a*, we see that in the steam-with-ice curve the point D, having the same temperature t_1 as the point C of the steam-with-water curve has, must, while situated in the isothermal line B D passing through C, be away from C at the side where the pressure is less than at C; or it must lie between C and the coordinate axis Y A produced past A.

This may be regarded as very nearly establishing that the curves cross one another, as drawn in fig. 1 *a*. It shows that they do not, as in fig. 1 *b*. Up to the present stage, however, the reasoning does not exclude the suppositions:—1st, that the curves might meet tangentially in the triple point T, and pass on without crossing; 2nd, that they might cross in the triple point, meeting each other there tangentially; 3rd, that the steam-with-ice line might absolutely stop short in the triple point.

The first and second of these remaining suppositions, depending, as they do, on supposed tangential meeting instead of meeting or crossing angularly, the author thinks very unlikely. One reason is that the condensed water-substance in contact with the steam makes a perfectly sudden change in its character in changing from water to ice or from ice to water; and he therefore thinks that in the curve which represents steam with water above the triple point, and steam with ice below it, we should expect to find a sudden change of direction at the point where this great physical change suddenly takes place.

Another reason against the first of these suppositions will be given in what follows almost immediately, by a proof that after meeting in the triple point in rising from lower temperatures, they cannot go on further without crossing. The third supposition, namely, that the steam-with-ice line might stop short in the triple point, the author thinks very unlikely to be the truth; but he is not aware of any experimental proof to offer against it.

Now, that the curves, after meeting in the triple point in rising from lower temperatures, cannot go on further without crossing, will be proved if it be shown that on the supposition of the steam-with-ice curve not stopping short on rising to the triple point, it must, on passing that point, have its course on the side of the steam-with-water curve remote from the coordinate axis Y A; or, in other words, if it be shown that, for any temperature t_2 above the triple point, the pressure of steam with water is less than the pressure of steam with ice.

This can easily be done by a demonstration quite like the one already given for a temperature below that of the triple point; and a brief sketch of it will here suffice.

Let us imagine that we have a cavity of variable dimensions, such as a cylinder with a piston which can be loaded so as to apply any desired pressure to fluid substance enclosed within. Let this vessel contain steam with ice at a temperature t_2, which is above that of the triple point; and let the cylinder be immersed in a bath maintained constantly at the temperature t_2. Let the pressure of the steam with ice for this temperature be called p_2.

Now increase the pressure by an infinitely small amount δ, making it $p_2+\delta$. While this is kept applied to the steam, the steam is by it kept going down to the state of ice; and thus we can conceive of the whole or any desired part being converted quite gently to ice*. Next, while maintaining the pressure p_2 or $p_2+\delta$ in

* The fact that the ice being rigid would oppose a mechanical obstruction to the complete pressing of the steam down to ice by a piston, may be noticed in passing, but it does not introduce any theoretical difficulty into the reasoning.

he steam, if any remains, or in the water next to be introduced, introduce a particle of water. Instantly the ice begins to melt, and falls in temperature, at the place of contact with water, to the temperature of water with ice for the applied pressure p_2 or $p_2+\delta$; that is, to the point V in the figure. But the surrounding bath is warmer than this, and so a decided difference of temperature is maintained, involving a rapid conduction of heat from the warmer bath to the colder melting ice and the cold water in contiguity to that ice. There can be no repose till all the water-substance originally enclosed as steam with ice has become water; because, while the steam can pass gently to ice under the pressure p_2, on the supposition that some particle of ice is kept present, and will be forced down by the infinitely small excess of pressure δ, the ice must briskly rush to the state of water. But we know we can have steam present in repose with water at the maintained temperature t_2 if we make the pressure small enough. An infinitely small abatement of pressure will not counteract or reverse the change which has been briskly taking place; and so the pressure must be made decidedly lower than either $p_2+\delta$ or p_2 to allow of the water resting in equilibrium in contact with steam at the temperature t_2.

That is to say, referring to fig. 1 *a*, on any isothermal line, such as F G, the point H, where it is cut by the steam-with-water line, must be nearer to the axis Y A than is the point G, where it is cut by the steam-with-ice line.

This, then, closes the course of reasoning entered on hitherto in these pages, and establishes (the author thinks with very little if any room left for doubt) that the two curves do not cross as in fig. 1 *b*; and that in meeting at the triple point, they do not meet and pass tangentially without crossing, but that they must cross as in fig. 1 *a*.

The conclusion here arrived at the author thinks may admit of experimental verification; and he thinks it opens a desirable field for further and more perfect experimental researches than have hitherto been made on the coexisting pressures and temperatures of steam and other gaseous substances, each in contact with its own substance, either in the liquid or in the solid state, at temperatures ranging above and below the triple point for each substance. Without its being necessary to make experiments on substances in the conditions represented by the dotted extensions of the curves past the triple point, he thinks that very accurate experiments might show, for steam, an obtuse re-entrant angle or corner at T, in the line L T N, which appears not to be one curve, but two distinct curves meeting in T, and crossing each other at that point.

Through an examination which the author has made of the experimentally derived curve given by Regnault * for what is shown as L T N here in fig. 1 *a*, he finds that the curve seems to show a slightly perceptible feature of the kind here anticipated—a slight re-entrant angle, or at least a slightly flattened place, or place of diminished curvature at the triple point; but this feature does not appear sufficiently marked to admit of its being relied upon as a decisive experimental confirmation of the theoretical view here submitted.

The author also submitted to the Meeting the following additional considerations on the subject.

It can easily be shown that the *perpetual motion* would be theoretically attainable unless (1) the pressure of steam with ice for a temperature t_1, which is below the triple point, were less than the pressure of steam with water for the same temperature t_1; and also (2) unless the pressure of steam with water for a temperature t_2, taken above the triple point, were less than the pressure of steam with ice for the same temperature t_2.

To prove the first of these, we have to observe that at t_1, which is below the triple point, in pressing steam down into water, we give mechanical work to the substance (call this *a*). Then when we insert ice, there is a finite difference of temperatures, with conduction of heat out to the bath; now by making this heat pass, not by conduction, but through a thermodynamic engine (an air-engine for instance), we can obtain work, which let us call *b*. During this freezing, too, we get back from the water-substance a little work, owing to the expansion of the water in freezing under the presure p_1 (call this *c*). Next allow the volume to

* Mémoires de l'Académie des Sciences, 1847, plate viii.

increase while arranging that the ice shall be evaporating into steam under the temperature of the bath t_1; we obtain mechanical work, which call d.

Now if, in this expanding process of ice to steam, the pressure were as great as p_1, which was the pressure during the compressing to water, we would get back on the whole from the piston all the work we gave to it; that is, the two portions c and d of work got back would together be as much as we gave, namely a; and we would have made a clear gain of the work b obtained from the thermodynamic engine.

A like proof could be given in respect to the second case—that in which the temperature is above the triple point.

A slight extension of this reasoning will prove that the curves, in crossing at the triple point, cannot cross tangentially.

This can be seen obviously from the consideration that the work obtainable by the thermodynamic engine is proportional to the difference of the temperatures between which the heat is transmitted; and that the difference between the work given to the piston of the cavity in compressing steam to water, and that obtained back again during the evaporation of the ice to steam, and then pressing the steam when the evaporation is complete a little down till it attains again its original pressure and volume, will be proportional, very approximately, to the difference of the pressures existing during the compression of steam to water, and the expansion of ice to steam, which latter pressure let us now call p_1'. Also let us call the temperature of the triple point t_0.

Thus it is obvious that we must have, as long as we keep very near the triple point,

$$p_1 - p_1' \propto t_0 - t_1.$$

And this shows that the crossing of the curves must be angular, not tangential.

The author further suggested that the reasoning here adduced may be followed up by a quantitative calculation founded on experimental data, most if not all of which are already available, by which calculation the difference of the pressures of steam with water and steam with ice for any given temperature very near the triple point may be found with a very close approximation to the truth.

Astronomy.

On some new Points in the Mounting of Astronomical Telescopes. By Howard Grubb, *C.E., F.R.A.S.*

The very great inconvenience attendant upon the use of the ordinary position-circle of a micrometer divided on a metallic limb, and the necessity of having small lamps hung on to the micrometer for producing that very useful character of illumination of the wires known as the "dark field," has induced the author to introduce some modifications in this (to the observer at least) very important part of an equatorial instrument.

These modifications have already been applied with success, and for the first time (as far as the author is aware) to a 7-inch refracting telescope now in course of erection at the Observatory of the Royal Artillery Institute, Woolwich; and the author has (in consequence of this success) been ordered to adapt them to the Great Equatorials now in course of construction for the Royal Observatory, Edinburgh, and the Observatory of the Lord Lindsay, Aberdeen*.

The rack-and-pinion tube carrying the eyepiece or micrometer revolves freely in the casting which forms the lower end of the telescope-tube, and carries a brass plate (all cast in one piece), on which is cemented a flat ring of plate glass, muffed on back and in front varnished with an opaque varnish. Through this varnish the divisions are cut, so that on being illuminated from behind the divisions appear bright upon a black ground. The vernier is similarly treated, and the whole of this circle, being covered with a cap, with a glazed window only sufficiently large to expose the vernier and about 15° of the circle, is protected from possible injury

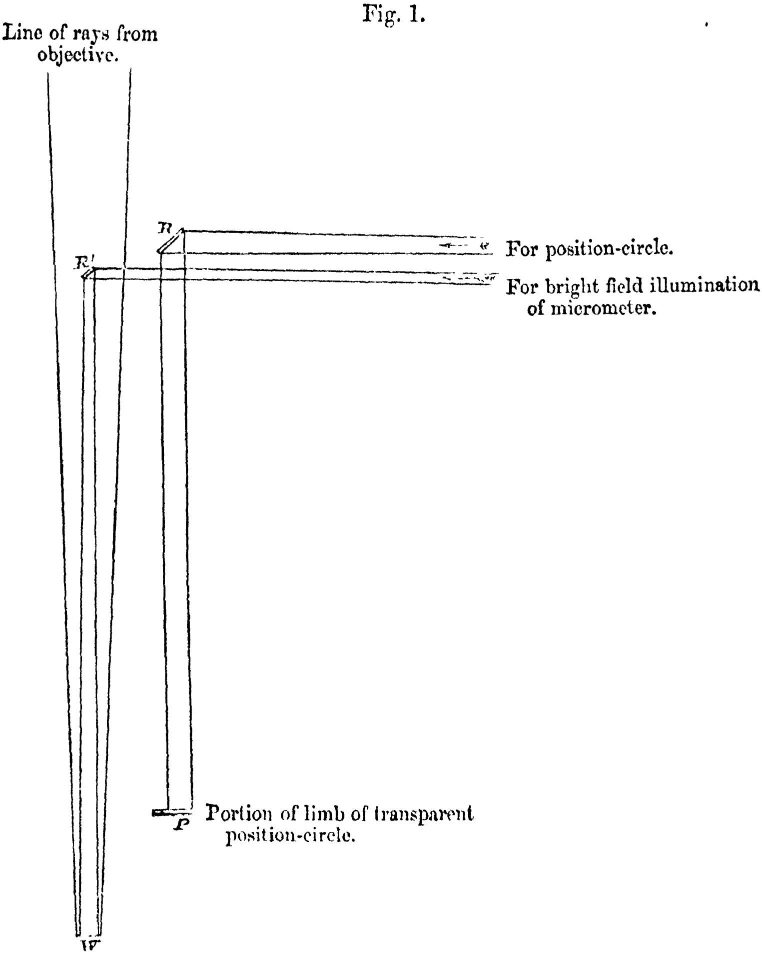
* The breech-piece and position-circle of the Woolwich Equatorial was here produced.

and is read most conveniently through this window, being illuminated by a beam of light constantly directed upon it from a lamp hanging on end of the declination axis, as will be afterwards explained.

Between the fixed casting which forms the end of the telescope-tube and that which revolves in it is another metallic circle cut into 360 teeth on edge, and with 90 holes drilled accurately on face; into the teeth on edge is geared a screw which is mounted on fixed casting, one revolution of which is of course equal to an angular movement of 1°.

In the other (outer) movable brass circle is mounted a steel pin working up and down in a small cylinder; this pin, being pressed down by a small spiral spring,

Fig. 1.



enters into one or other of the 90 holes in the intermediate circle and thus clamps the whole eye end to the intermediate circle, in which condition a slow motion is obtained by the endless screw. When it is desired to move the eye end through a large angle, the rack-and-pinion tube is grasped by the hand; and in doing so the hand almost necessarily grasps also a small steel trigger, which lifts the steel pin out of the hole, frees the movable circle, and allows it to be placed in any

angular position. When the desired position is approximated and the trigger relieved, the pin drops into the nearest hole, and the endless screw is then used for final setting.

The diagram explains the various matters of illumination.

From a lamp hanging upon the end of the declination axis is sent a beam of slightly divergent light through this axis, which is hollow; this slightly divergent beam is utilized for six different purposes, three portions of it being reflected out in different directions to illuminate portions of the declination circle, of which one is for a long reader for setting from eye end, and the other two for micrometer microscopes subdividing the 10′ division of circle into single 1″ arc.

None of these are shown in diagram; but the other three purposes for which the light is utilized, viz. for position-circle, bright field illumination, and dark field illumination of micrometer, are shown.

The position-circle illumination is very simple (see fig. 1); a single reflector R, attached to the inside of the tube, directs a constant beam of light on the back of the glass circle at P.

The bright field illumination is effected by a very small central reflector R′, which sends the light directly into the field of the micrometer.

This method is, the author believes, now generally considered to give the best results, and has, as far as he is aware, but one disadvantage, viz. that the arm which supports the small mirror produces a little diffraction, and consequently deterioration of definition.

This objection is in some measure reduced by making the arm and mirror removable at pleasure by pulling or releasing a string, so that while actually observing, it can be removed and replaced instantaneously.

In devising the dark field illumination, the author started on the hypothesis that there were two essential points to keep in view, viz. that the lines should be illuminated on both sides (not one), and that the angle at which the light should be thrown upon the wires should be very great, so that the blackness of the field as seen through the eyepiece should not be injured.

The best results were obtained by placing four prisms of total reflection round the field of the micrometer, just behind the wires, and of such an angle that the light thrown upon them should be reflected upon the wires at an angle such as is shown in diagram fig. 2, where W is the position of wires in focus of objective.

In order that this scheme of illumination should be carried out effectually from the light of a single lamp hanging on the declination axis, it is necessary that a certain annular portion of the micrometer which embraces these prisms should be constantly illuminated from this lamp; and this is effected in the following way: a portion of the slightly divergent beam of light, shown in fig. 2, proceeding from the lamp on the declination axis is passed through a very low-power convex lens, *l*, which renders the beam slightly convergent.

This is not necessary, but a mere matter of convenience, as it reduces the necessary size of the reflector and lens afterwards required. The light is now taken up by a reflector, R, within the tube, and directed towards the eye end at such an angle that it crosses the axis of the telescope just at the inner end of the eyepiece-tubes, X; hence it is passed through a piece of glass of a peculiar shape, P P, which is called, for want of a better name, an annular prism lens. This piece of glass has a hole cut in it large enough to admit the whole pencil of light from the object-glass.

The use of this annular prism lens is twofold:—

1st. It has to alter the direction of the beam of light, before diagonally thrown across the tube R X, to that parallel to the axis of the telescope; and

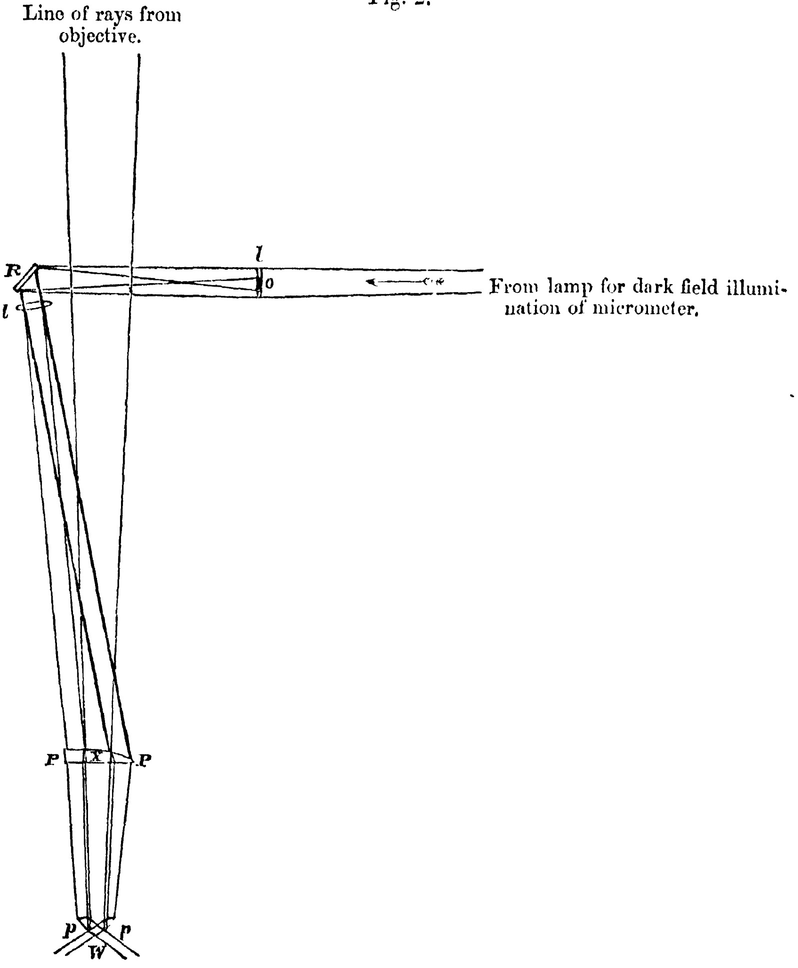
2nd. It is necessary that it should have a slightly converging effect to reduce the size of the illuminated circle it produces.

This arrangement so far performs perfectly in all but one particular. It throws a strong beam of light constantly upon the four prisms, *p*, *p*, and illuminates the lines well; but although no direct light can enter into the field from the mirror placed so far out of the cone of rays from the objective, still the light thrown against the side of the eyepiece-tube is sufficient to completely destroy the effect of this illumination. The difficulty, however, has been completely removed in this way.

It should first be mentioned that the eyepiece or micrometer-tube is made double, an outer parallel tube and an inner taper one; and it is between these two that it is required that the light should be brought to the four prisms or micrometers, any light shining into the inner tube doing mischief by injuring the blackness of the field.

On the lens used to give a slight convergence to the light is placed a circular opaque disk *o*, of a certain size easily ascertained; a lens of a suitable focus

Fig. 2.



being then placed near the reflector, an image is formed of that opaque disk just over the eyepiece-tube at X, and of such a size, when properly adjusted, that no light can possibly enter the inner tube.

Thus while not a single ray of light can by any possibility enter the inner tube, a flood of light is sent down between the inner and outer tubes and directed upon the four prisms in whatever angular position they may be.

It only remains to say that both the intensity and colour of the light for both characters of the illumination are under complete control of the observer while actually observing.

One other matter is perhaps worthy of note.

The want of a convenient method of mapping nebulæ or faint stars by a reticulated diaphragm of bright lines in the field of view has long been felt, and the various methods of using diamond scratches on glass or illuminated lines are subject to objection and troublesome to manage. A simple method of using an image of such a diaphragm instead of the actual diaphragm itself here suggests itself.

Referring to the portion of the rays used for bright field illumination, and shown in fig. 1, suppose the small diagonal mirror, R′, to be replaced by an equally small prism having such a convex power that it forms an image of any object at the end of the declination axis exactly in the same plane as the image found by the objective; then any kind of reticulated diaphragm of bright lines on the dark ground can be placed on the end of the declination axis, which would have a suitably prepared carrier for them, and their image would be seen in the field of the telescope of any colour and any intensity desired.

Résultat de mes Observations dans l'Inde sur l'Eclipse du 12 *Déc.* 1871. *Par* Dr. Janssen.

Je considère d'autant plus comme un plaisir de donner ici ce résumé que l'Association Britannique par l'organe de son illustre Président de l'année dernière m'avait généreusement proposé de se charger de mon voyage dans l'Inde pour le cas où l'exécution de ce voyage eût rencontré en France des difficultés.

Heureusement notre Gouvernement comprit l'importance de ces questions scientifiques et voulut faire les sacrifices nécessaires; mais je n'en suis pas moins reconnaissant envers la savante Association.

On sait que le but des expéditions était de déterminer la nature de la couronne sur laquelle, malgré les observations de 1869 et 1870, planaient encore bien des doutes.

Le peu d'étendue que doit avoir cette note ne me permet pas d'examiner les travaux antérieurs sur la couronne ni même les résultats obtenus par les autres observateurs le 12 Déc. 1871, je me bornerai à exposer mes observations personnelles.

Pour l'étude de ce grand problème de la *couronne* je me suis attaché surtout à réaliser deux conditions capitales.

1°. Le choix d'une station où le ciel fût d'une grande pureté au moment du phénomène.

2°. La réalisation d'un instrument collecteur de la lumière très-puissant de manière à obtenir un spectre très-lumineux de la *couronne* (c'est le défaut de lumière qui jusqu'ici a induit en erreur sur la véritable constitution du spectre de la couronne).

Pour avoir un bon choix de la station je partis de France deux mois avant l'éclipse, et je parcourus presque toutes les stations de la ligne centrale depuis Ceylon jusqu'à la côte Malabar. Le massif montagneux des Neelgherry me parut offrir les meilleures conditions sous le rapport de la pureté du ciel. En étudiant ces montagnes j'ai remarqué que tous les matins, au lever du soleil, le vent s'élevait de l'orient et amenait des nuages, mais que ce vent cessait bientôt, en sorte que ces nuages s'arrêtaient et ne couvraient que la portion orientale du massif Il résultait de cette remarque que les chances étaient beaucoup plus grandes dans la région occidentale du massif. Je m'établis donc dans cette direction. Ma station fut une montagne près Shoolor, petit village Indien à environ 7000 pieds au-dessus du niveau de la mer*.

Je viens maintenant aux instruments.

L'étude des résultats obtenus en 1869 et 1870 m'avait démontré que c'est le manque d'intensité lumineuse des spectres de la couronne qui avait empêché d'obtenir des résultats plus décisifs. Mes dispositions optiques eurent donc pour but d'obtenir un spectre de la couronne très-lumineux: je construisis un télescope d'environ 40 centimètres de diamètre, et $1^{m}\cdot43$ de distance focale. Ce télescope donne des images environ 16 fois plus lumineuses que celles d'une lunette astronomique ordinaire de même ouverture. Le chercheur était disposé de manière que l'un des yeux

* Je remercie ici les autorités de l'Inde et en particulier Lord Napier, de l'appui qu'ils m'ont donné.

étant au chercheur, l'autre pouvait regarder dans le spectroscope du télescope. Cette disposition est très-importante ; elle permet au même observateur de voir le phénomène, et d'en obtenir en même temps l'analyse lumineuse.

Le spectroscope était également très-lumineux et mis en rapport de foyer avec le télescope.

Enfin je pris des dispositions pour réaliser l'obscurité autour de moi pendant l'observation afin de conserver à ma vue toute sa sensibilité.

Voici maintenant le résumé de l'observation de l'éclipse.

Le 12 Décembre à Shoolor au lever du soleil les nuages arrivèrent comme d'habitude et couvrirent le Dodabetta; mais ils n'arrivèrent pas jusqu'a nous, et nous eûmes un temps d'une pureté admirable.

La couronne se montra avec des formes et une constance d'aspect qui ne permet pas de l'expliquer par la diffraction.

Le spectre des régions supérieures de la couronne montra immédiatement la raie verte déjà signalée et si remarquable ; mais elle était accompagnée des raies de l'hydrogène pâles mais bien perceptibles.

Ainsi le spectre de la couronne n'est pas continu comme la plupart des observateurs de 1868, 69, 70, l'ont observé ; mais, même dans les régions supérieures il nous présente indépendamment de la raie verte les principales raies de l'hydrogène.

En avançant vers la base de la couronne le spectre gagnait en vivacité, les raies de l'hydrogène s'accentuaient davantage. La raie obscure D s'est montrée.

Dans le vert j'en ai vu aussi quelques autres plus fines ; mais cette vision était à la limite, ce qui s'explique très-bien, parce que j'avais ouvert la fente autant que possible, mais de manière à voir toujours les principales raies du spectre solaire.

Je plaçai ensuite la fente de manière à couper à la fois le disque de la lune, une protubérance et diverses régions de la couronne.

Le phénomène fut très-beau et très-concluant.

Sur la lune, spectre très-faible presentant les lignes de l'hydrogène très-courtes, très-faibles, prolongeant les raies très-vives de la protubérance.

La protubérance ne donnait pas la raie verte, tandis que cette raie commençait immédiatement au-dessus dans la couronne ; enfin la raie D fut aussi visible.

D'autres observations confirmèrent ces résultats pour le spectre de la couronne.

La polarisation de la couronne est vive, elle est radiale et à son maximum d'intensité à quelques minutes de la chromosphère.

Ce résultat explique comment quelques observateurs ont trouvé la lumière de la couronne non polarisée : c'est qu'ils interrogeaient des parties de la couronne très-voisines de la chromosphère, là où l'émission propre l'emporte sur la reflexion. Mais plus haut l'émission étant plus faible, la réflexion devient perceptible, et c'est là aussi qu'on trouve les raies obscures du spectre solaire.

En résumé. Il paraît aujourd'hui démontré par les observations de 1869, 1870, 1871 :

Que le phénomène de la couronne des éclipses totales est dû à une enveloppe gazeuse appartenant au soleil ;

Que cette enveloppe est lumineuse par elle-même, au moins dans les parties voisines du soleil ;

Qu'elle possède une densité excessivement faible et une température beaucoup plus basse que celle de la chromosphère ;

Que le gaz hydrogène en forme un élément principal ;

Que cette enveloppe gazeuse n'est nullement dans un état statique, mais qu'elle présente des formes très-irrégulières, ce qui s'explique par les mouvements prodigieux de matières qui ont lieu dans la chromosphère et qui font pénétrer dans cette enveloppe d'immenses jets de matières qui en troublent continuellement l'équilibre et en changent la densité en ses diverses parties.

Cette couche formant une enveloppe très-distincte de la chromosphère, il y a lieu de lui donner un nom. Je propose de l'appeler *l'atmosphère coronale*.

Light.

Refraction and Solar Spots. *By* J. H. Brown.

On the Action of Quartz on Ultra-Violet Rays. *By* Professor Croullebois.

On Tubes Phosphorescent by Friction. *By* Professor Croullebois.

On Focal Lines. *By* Professor J. D. Everett, *D.C.L.*

On a Difficulty in the Theory of Aberration. *By* Professor J. D. Everett, *D.C.L.*

On Mirage. *By* Professor J. D. Everett, *D.C.L.*

On Astronomical Refraction. *By* George Forbes.

The errors of the refraction tables are best shown by noticing the variations in the North Polar Distances of stars observed with the Greenwich Transit-circle as determined by observations of different nights. They are sometimes very considerable. Humidity is doubtless one of the most important points to be attended to. But this correction is difficult to apply, for its value is at present unknown. The author wished to point out a minor correction, which, however, becomes important in some cases, which can be easily determined, and which, so far as he knows, has not been hitherto alluded to. This is the effect due to *a difference in the height of the atmosphere at adjacent stations* on the meridian (if a meridian instrument be used), as shown by the barometer. The superabundant air will act as a prism of air, and may possibly introduce sensible errors.

The theory of correcting for this is as follows:—

In the differential equation to the path of a ray, viz.

$$dr=\frac{d\mu}{\mu}\tan i,$$

i is the inclination of the ray to the normal to a surface of equal density (the surfaces of equal density being supposed to be concentric). But in the case considered, where the barometer varies at adjacent stations, the surface of the earth is not a surface of equal density, but is inclined to it, so that the sections of the surface of equal density and the surface of the earth, by a plane in the meridian, include an angle α, which can be easily tabulated for different values of the barometric differences. Hence, in using Bessel's refraction tables, where the argument is the angle i, we ought to use, not the observed zenith-distance Z, but the angle $Z\pm\alpha$.

By comparing good observations at stations five miles apart, the author found that the barometers sometimes differed by 0·010 inch. The effect of this difference on the places of stars is as follows:—

For stars whose	zenith-distance is	60°	the correction	is about	0″·2
”	”	80	”	”	1·0
”	”	85	”	”	3·6
”	”	90	”	”	20·0

These effects then are very sensible. Nor is it likely that the barometer observations compared are exceptional.

The existence of this source of error was clearly detected in the Greenwich observations, by comparing them with observations of the barometer at adjacent stations. Every test that has been applied confirms the opinion that, by the application of this correction, a considerable increase of accuracy would be obtained in stars of great zenith-distance.

The Action of Sunlight on Colourless and Coloured Glass. *By* THOMAS GAFFIELD, *of Boston.*

The author's experiments on this subject, of which some accounts have appeared in American and European scientific journals, cover a period of nine years, and embrace some eighty different kinds of glass, of English, French, German, Belgian, and American manufacture,—of rough and polished plate, crown, and sheet window glass, of flint and crown optical glass, of opal and ground glass, of coloured pot-metal, flashed and stained glass of various colours, of glass ware, and glass in the rough metal. They were carried on chiefly upon the window-sills and roof of the author's house in Boston, in a position exposed to the full force of the sun's rays during the whole or greater portion of every day, only being protected by covers in the event of snow-storms.

The usual size of the glasses exposed is four by two inches, and several hundred specimens show the effect of sunlight in producing a change of colour by exposure from one day in summer to several years. These changes in the colourless glasses are from white to yellow, from green to yellowish green, from brownish yellow to purple, from greenish white to bluish white, and from bluish white to a darker blue. By the colours of colourless glass are meant those which are seen in looking through the edges of the glass. They are not noticed in looking at the surface in our windows, unless a white curtain furnishes a contrasting background.

It is a curious fact that, while these various glasses before exposure can be submitted to great heat in a glass-stainer's kiln without any change, all the exposed and changed specimens can be restored to their original colour by being placed in the same kiln during a single fire. A second exposure to sunlight will reproduce the same yellow and purple colours as before; and this process of coloration by light and decolorization by heat can be carried on indefinitely.

During the last year, the author commenced an experiment with pot-metals, not of the primary colours, but of the intermediate ones, which most nearly approach those produced in colourless glass by sunlight exposure. In every specimen of the brownish, yellowish, and rose or purple colours thus exposed, astonishing changes in colour or shade in a short time were observed. In some instances a few days of exposure in the month of June of the present year sufficed to show the commencement of the sun's influence. These changes were from a coffee-colour to a rose, from amber, yellowish, brownish, and purple to darker shades of the same colours.

Inasmuch as this class of pot-metal colours was used in the painted windows of past ages, and as flashed and stained colours are subject to change in the colourless body of the glass, may not this series of experiments go far to solve many interesting questions regarding the alleged superiority of the old cathedral glass? The fact of coloration or change of colour or shade by sunlight being established, must we not transfer some of our praise for the old artists in glass to the wonderful pencil of the brightest luminary of the heavens, which, during the centuries, has noiselessly but unceasingly been at work, deepening and mellowing the colours of all the windows of the venerable cathedrals of the world?

Exactly what this wonderful alchemy is, and what are the methods of its operation, are questions on which various opinions may be given, but which only a careful consideration and comparison of the observations and theories of many different scientific men can accurately decide. Some have attributed it to the presence of oxide of iron, some to arsenic, and some to sulphur in the constituent materials of the glass. Some think oxide of manganese (singular as it may seem used as a *decolorizer*) to be the great *colourist* in this matter. The author thinks that in many coloured and colourless glasses it plays a very important part in the effects produced. But in some experiments made with glasses containing no manganese, decided changes of colour from greenish to yellowish have been produced.

Perhaps the question cannot be accurately solved until some glass-manufacturer will make, with great care and for this special purpose, a series of specimens of colourless and coloured glass, which shall be exposed for months and years to the influence of sunlight. Knowing the exact constituents of each specimen, a good foundation could be laid for a thoroughly scientific investigation of the subject.

Since the publication of the results of the author's first experiments, made in 1863, there has been quite a change in the original colour of some of the window glass made in Europe. The author understands that many of the manufacturers have given up the use of oxide of manganese, or reduced the quantity employed. The result is, that the brownish-yellow coloured glass, which used to change to a purple hue in a year or less, is now replaced by a light bluish green, which shows little or no change after years of exposure. It will be a practical result of the inquiry suggested above, if colourless glass of all kinds shall be made which shall not change in colour by sunlight exposure, and but slightly in shade. Especially is it important to photographers, in any operations requiring all the light which they can obtain, not to have glass in their skylights which, after a few months or years of exposure, shall be robbed of a great proportion of its power to transmit the chemical or actinic rays, by a change to a yellow or purple hue, which, in time, might cut off almost as much actinic effect as if it were ground or covered with enamel on one of its surfaces. The author made some photographic experiments to show this deteriorating effect, by exposing sensitive paper under glasses of original colour, and those of the same kind changed by sunlight, and witnessing the very perceptibly different shades of darkening produced.

This action of sunlight must not be confounded with rust or stain occasioned by exposure to atmospheric influences, which occasions sometimes a roughening and sometimes an iridescence upon the surface; while sunlight action, which has no disintegrating effect on the outside, extends throughout the body of the glass.

On the Spectrum of Hydrogen. By ARTHUR SCHUSTER.

Hydrogen is one of the gases said to exhibit more than one spectrum. Under a pressure greater than about 5 millimetres it is said to show a spectrum of shaded bands. The spectrum of hydrogen which is seen in the heavenly bodies appears under a pressure from 5 millimetres down to the lowest pressure which can be obtained by Sprengel's pump, where a new spectrum of lines suddenly appears. Plücker, who discovered the band-spectrum of hydrogen, was first of the opinion that it was due to the last traces of air. Finding, however, that its bands did not coincide with the bands of air, he attributed it to hydrogen. Ångström has recently given his reasons against this supposition, and believes it to be due to acetylene. My own experiments have led to the confirmation of Ångström's opinion. Generally two distinct causes may introduce a hydrocarbon into the vacuum-tube:—

1. The gas passing through india-rubber tubes will carry with it small pieces of india-rubber.
2. All the vacuum-tubes are more or less greasy.

These two causes I consider sufficient to produce all the effects observed by Plücker. Wüllner, however, found this spectrum so well developed that we must look in his experiments for a more constant source of error. This, I believe, is found in the greased stopcocks which he used to shut his vacuum-tubes. Examining the spectrum of oxygen, he discovered two new spectra which he found later to be due to carbon-compounds introduced into his vacuum-tubes by the grease of the stopcocks. The quantity of solid matter carried away by a current of air passing through an india-rubber tubing is not so small as might at first sight appear. Tyndall, in his experiments on actinic clouds, mentions the effect produced by an india-rubber joint through which the gas, subjected to examination, had passed. In order to eliminate the effect of the tubings, a drop of water was introduced into the vacuum-tube, which was boiled after the vacuum had been made. When all the air was expelled the spark was allowed to pass. It was now found that the band-spectrum varied much with the different tubes. Those which had been well cleaned before being used showed it only very feebly. Ångström's supposition that this spectrum is due to acetylene is therefore very plausible.

I obtained the spectrum of ammonia by the following arrangement:—A few drops of a strong solution of ammonia in water were introduced into the vacuum-tube, and the induction-current was allowed to pass while the pump was being worked.

Thus a vacuum is obtained sufficient to allow the passage of the current, and at the same time the gas is constantly renewed, which prevents its decomposition. The spectrum of ammonia consists of a broad greenish-yellow band, the wave-length of which was determined by interpolation to be 5686 to 5627 10th metres.

Having no Sprengel's pump at my disposal, I could not examine hydrogen under the conditions in which it is said to give a third spectrum: suffice it to say that Plücker has examined it under those circumstances, and does not mention any new spectrum. Angström has shown that all the lines of this spectrum coincide with lines of sulphur (which might be introduced by the caoutchouc tubings). Wüllner says that the general appearance of the sulphur-spectrum is a different one; but this may be due to the circumstance that the sulphur-spectrum was never examined under so minute a pressure.

On the Application of Photography to copy Diffraction-gratings. By the Hon. J. W. Strutt.

Great interest has always attached itself to the beautiful phenomena discovered by Frauenhofer, which present themselves when a beam of light falls on a surface ruled with a great number of parallel and equidistant lines. Their unexpected character, the brilliant show of colour, and the ready explanation of the main points on the principles of the Wave-theory recommend them to all, while the working physicist recognizes in them the key to the exact measurement of wave-lengths, which has been so splendidly used by Ångström and others.

The production, however, of gratings of sufficient fineness and regularity is a matter of no ordinary difficulty. Indeed the exactness required and obtained is almost incredible. The wave-lengths of the two sodium-lines differ by about the thousandth part. If in two gratings, or two parts of the same grating, the average interval between the divisions differed by the fraction, the less refrangible sodium-line of one would be superposed on the more refrangible corresponding to the other. In point of fact the gratings ruled by Nobert of Barth, to whom the scientific world has been greatly indebted, are capable of distinguishing a difference of wave-length probably of a tenth part of that above mentioned. But in order that the D-lines may be resolved at all, there must be no average error (running over a large part of the grating) of $\frac{1}{1000}$ part of the interval between consecutive lines. When it is remembered what the interval is (from $\frac{1}{1000}$ to $\frac{1}{6000}$ of an inch, or even less), the degree of success which has been reached seems very remarkable.

A work requiring so much accuracy is necessarily costly—the reason, probably, why gratings fit to be used with the telescope for the purpose of showing the fixed lines are comparatively rare. The hope of being able to perfect a process for the reproduction of gratings at a comparatively cheap rate has induced the author to return at the first opportunity to the experiments described in a Preliminary Note read before the Royal Society in June last. Although the subject is as yet by no means exhausted, the author thought it worth while to bring before the Association an account of the progress that has been made, with specimens of the results.

The method of procedure is very simple. A dry plate prepared by any photographic process on a *flat* surface of glass or other transparent material not affected by the fluid media employed is brought into contact with the ruled surface of the grating in a printing-frame, and exposed to light. In the author's first experiments he used exclusively as a source of light the image of the sun in a lens of short focus placed in the shutter of a darkened room; but so small a source is not necessary. The light from the clouds or sky reflected by a mirror through a hole several inches in aperture will be sufficiently concentrated if the frame be a few feet distant. The author has not as yet specially investigated the point, but he believes that if the light be too much diffused, the experiment would fail. Much would, no doubt, depend on the perfection of the contact—an element very likely to vary. The variable intensity of diffused daylight, which it is almost impossible to estimate with precision, has induced him to use exclusively in his later experiments with ordinary photographic plates the light of a moderator lamp. This, with globe removed, is placed at a distance of 1 or 2 feet from the printing-frame, the distance being carefully

measured. Working in this way there is little difficulty in giving consecutive plates any relative exposure that may be required. A collateral advantage is the possibility of operating at any time of the day or night.

With regard to the preparation of the plates, the author has latterly been using the tannin process introduced by Major Russell. A preliminary coating with dilute albumen is generally advisable, as any loosening of the film from the glass must be avoided on account of the distortion that it might introduce. In some states of the collodion an edging of black varnish put on after the exposure is sufficient to hold the film down. The glasses, after being coated with collodion (Mawson's was used), are immersed as usual in the silver bath, and then allowed to soak in distilled water, best contained in a dipping-bath. They are then washed under a tap for about half a minute, and put into the tannin solution (about 15 grains to the ounce) held, in the author's practice, in a small dish. The author usually prepares his plates in the evening, standing them up to dry on blotting-paper. In the morning they are in a fit state for use. Artificial heat might no doubt be used if a more rapid drying were desired.

At a distance of 1 foot from the lamp the exposure required is four or five minutes. The development is the most critical part of the process. The pyrogallic solution should contain plenty of acid (acetic or citric), and its action must not be pushed too far—the mistake which a photographer accustomed to negative work is most likely to make. At this stage the spectra given by a candle-flame are not very brilliant, on account of the iodide of silver still covering the parts which are to be transparent. Any trace of fog is especially to be avoided. The author has experienced advantage in many cases from a solution of iodine in iodide of potassium applied to the film previously to fixing; but its action must be carefully watched, or too much silver will be converted. The iodide of silver is then cleared away with hyposulphite of soda or cyanide, followed by a careful washing under the tap.

With regard to the gelatine copies, the author has not much to add to the account read before the Royal Society. The process is very simple and some of the results very perfect, but he has not hitherto succeeded in sufficiently mastering the details. Plates apparently treated in precisely the same manner turned out very differently. That difficulties should arise is not very extraordinary, considering the novelty of the method; but it is curious that some of the very first batch prepared are among the best yet produced. The value of the results is so great, that the author has no intention of abandoning his attempts, and perseverance must at last secure success.

The author then said a few words about the performance and prospects of the new copies. Their defining power on the fixed lines in the solar spectrum is all that could be desired, being, so far as he can see, in no way inferior to the originals. In the third spectrum the 3000 to the circle-gratings show the line between the D's, *if the other optical arrangements are suitable*. The fourth line of the group *b* is distinguished with the utmost ease. The author is not sufficiently familiar with spectroscopic work to make an exact comparison, but presumes that two prisms of 60° at least would be required to effect as much. The author is here speaking of photographs on worked glass. With ordinary patent plate, although very good results may be obtained if tested by the naked eye only, it is a great chance whether the magnifying-power of a telescope will not reveal the imperfect character of the surface.

With direct sunlight the light is abundantly sufficient; but it is here in all probability that the weak point of gratings lies. It should be distinctly understood that where light is deficient gratings will not compete with prisms. There are cases, however, where the scale might be turned by the opacity of all highly dispersive substances to the rays under examination. Even if glass be retained as the substratum, it may be used in a very thin layer, while prisms are essentially thick. The immense advantage of a diffraction-spectrum for the investigation of dark heat need not here be insisted on. Taking all things into consideration, it is probable that photographed gratings will supersede prisms for some purposes, though certainly not for all.

The specimens exhibited by Mr. Ladd are copies of two gratings by Nobert, each of a square inch in surface, the one containing 3000 and the other 6000 lines. The latter cost about £20.

On Atmospheric Refraction of Inclined Rays, and on the Path of a Level Ray. *By* JAMES THOMSON, *LL.D., Professor of Civil Engineering in Queen's College, Belfast.*

Many years ago, in considering, from a civil-engineering point of view, the path of a level or nearly level ray of light through the atmosphere, with special reference to corrections in observations with the levelling-instrument, the author found himself unable to rest satisfied with the views put forward on the subject in books on Practical Geodesy, or in any writings with which he was acquainted. The only views which he then met with were to the following effect:—

The atmosphere was regarded as consisting of an infinite number of infinitely thin horizontal laminæ, with a gradual increase of density in passing downwards through these laminæ, so that the density in each lamina would differ only in an infinitely small degree from that in the one immediately above it, or from that in the one immediately below it. It was then inferred that a ray of light, passing obliquely downwards through the laminæ, must, at each successive transition from one lamina into the denser one next below, suffer refraction so that its course must make a less angle with a normal to the laminæ in the denser lamina than it did with the same normal in the rarer one immediately above, and that the path of the ray must therefore be curved with the concave side downwards. From this reasoning, without noticing that its whole foundation, in oblique transition of the light across laminæ with gradual change of density in those successively traversed, vanishes in the case of a horizontal ray, authors have tacitly assumed that a ray proceeding through the atmosphere, so as to enter a levelling-instrument horizontally, should be expected to be curved with its underside concave. In one sense such a conclusion, in connexion with the mode stated in which it has been inferred, may be partly justified—that is, if the consideration be that a ray coming from a considerable distance so as to enter an instrument horizontally must have previously been descending obliquely through the nearly spherical level laminæ of the air which are rounded in correspondence with the figure of the earth. Rays arriving level at an observer's station from the rising or setting sun afford an instance of what is here referred to, and one in which the light has descended obliquely through the whole depth of the atmosphere. It may readily be admitted, from the usual reasoning cited above, that any such ray will be curved and concave downwards at all parts of its course where it is sensibly descending; but as the advancing ray gradually approaches to the level position with a gradual diminution down to cessation of oblique descent through the laminæ, it might still, so far as that reasoning would indicate, be held an open question whether the curvature of the ray would approach towards zero, or whether it would approach towards a maximum, or generally what might be the condition as to curvature or straightness of the ray, as the ray comes to be level.

The author proposed the question in 1863 to Professor Purser, of Queen's College, Belfast; and Prof. Purser, on the moment, made out an analytical investigation which depended on the proportionality of the sine of the angle of incidence to the sine of the angle of refraction holding good for infinitely thin laminæ differing infinitely little in density, and holding good to the extreme case in which the ray becomes parallel to the laminæ. This investigation appeared to the author of the present paper to be consistent with all physical conditions; and he regarded it as an hypothesis likely to be fully confirmed by experimental investigations, if at any time experiments bearing on the subject should be found practicable. From direct experiments, however, on the curvature of a ray of light in the atmosphere, no accurate results are to be hoped for, on account of the great and constantly varying disturbances to which the ray is subject, through changes in the distribution of heat and moisture in the air, and movements of its parts among one another, and other varying influences.

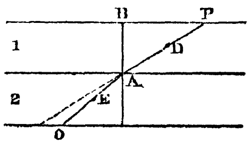
Prof. Purser's investigation, which from the first has been deemed by the author of the present paper to be of much interest and value, was to the following effect, the question being:—

To find whether a ray of light passing infinitely nearly horizontally through the atmosphere will be bent with a finite curvature, or not bent at all; and whether the curva-

ture approaches to a maximum or to a minimum as the direction of the ray approaches towards horizontality.

Conceive two laminæ, Lamina 1 and Lamina 2, each of the thickness λ. Conceive the density in each as being constant, but that there is a sudden increase of density in passing from the one to the other. Then the ray of light P A O will at A be suddenly bent or deflected from its previous line. This case may be substituted mathematically, when the laminæ are taken infinitely thin, for what actually occurs in the atmosphere.

Fig. 1.



Now in the atmosphere the deflection of the ray of light in passing from the middle of one lamina to the middle of the next, as from D to E, is evidently proportional to the thickness assumed for the laminæ, the thickness being small. Hence, if we take δ to represent the angle of deflection at A, we must bear in mind that $\delta \propto \lambda$ for any given angle of incidence, or that δ must be infinitely small when the lamina is infinitely thin. Let the angle of incidence P A B $=i$. Then, by the ordinary law of refraction assumed as applicable to this case,

$$\sin i=\mu \sin (i-\delta),$$

in which μ denotes the index of refraction for passage of a ray from one lamina to the next when the thickness of the laminæ is λ.

Hence $\frac{\sin i}{\mu}=\sin i \cos \delta-\cos i \sin \delta$, or by dividing by $\cos i$,

$$\frac{\tan i}{\mu}=\tan i \cos \delta-\sin \delta.$$

But δ must be infinitely small, the laminæ being infinitely thin. Hence for infinitely thin laminæ we have $\sin \delta=\delta$, and $\cos \delta=1$. Hence the previous equation becomes

$$\frac{\tan i}{\mu}=\tan i-\delta,$$

or

$$\delta=\frac{\mu-1}{\mu} \tan i.$$

Let D E, or its equal P A, the laminæ being infinitely thin, be denoted by s. Then $s=\lambda \sec i$.

Let the radius of curvature of the ray of light, or the radius of the circle touching the ray in the points D and E, be denoted by R, and then we have

$$\text{Curvature}=\frac{1}{R}=\frac{\delta}{s}$$

Hence

$$\text{Curvature}=\frac{\mu-1}{\mu\lambda}\,\frac{\tan i}{\sec i},$$

or

$$\text{Curvature}=\frac{\mu-1}{\mu\lambda} \sin i.$$

But since the curvature of the ray of light is independent of the small thickness which we may take for the infinitely thin laminæ, and can only vary with the angle of incidence i, we must have $\frac{\mu-1}{\mu\lambda}$ in the foregoing equation constant; and so we have

$$\text{Curvature} \propto \sin i,$$

which has its maximum value when i is a right angle; that is, when the ray is passing horizontally, or infinitely nearly so.

This shows that if the ordinarily assumed law of refraction be truly applicable to a ray of light passing extremely nearly horizontally through level laminæ of air of varying density, the curvature of the ray of light must approach to a maximum as the inclination of the ray approaches to horizontality. From this, if true, the step is natural, or inevitable, to the conclusion that, leaving out of account the rotundity of the earth, and conceiving the laminæ of constant density to be level planes, a ray

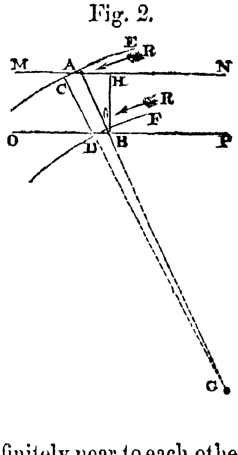
of light directed level so that if it were to traverse a straight path it would pass along an infinitely thin lamina of uniform density, but with less density above and greater below, *would be bent by virtue of the difference of the densities above and below it.*

It must, however, be admitted that there is something perplexing, or not quite satisfactory to the mind, in taking this final step to the perfectly level ray; for as soon as the inclination of the ray becomes zero the whole foundation and framework of the investigation fails, there being then no oblique passage of a ray from one lamina into another, no incident and no refracted ray, and consequently no ratio of sines of angles of incidence and refraction; though all these would be required to be discussed as if they existed in the case of every ray whose curvature is to be compared with that of any other. Still, as both Professor Purser and the author thought at the time, the investigation made the physical conclusion as to level rays seem highly probable; since, if it proves, as it seems to do, that a ray of light descending obliquely must move along a certain curved path, and that the curvature must increase as the inclination approaches towards horizontality, and also that the rate of change of curvature with change of inclination approaches towards zero as the inclination approaches towards horizontality, it must follow that a ray of light passing exactly level will be bent with the same curvature as one infinitely nearly level.

Several years later (in February 1870) a new investigation occurred to the author of the present paper. The new one is much simpler, and it is more general, and its reasoning holds good alike for level as for inclined rays. In fact the previous investigation, founded on the ratio of the sines of angles of incidence and refraction, and therefore in principle having no direct applicability to level rays, comes, when considered in connexion with the new one, to be a case of this more general one, seeing that under the undulatory theory of light the proportionality of the sines of the angles of incidence and refraction is not an ultimate fact or principle, but a consequence of retardation of the velocity of light in the denser medium. In the new investigation which will now be submitted the retardation of the velocity of light in the denser medium is taken as the basis of the reasoning.

Let M N and O P be two level surfaces in the atmosphere, and let each of these be supposed to pass through air of uniform density throughout each of them. They may be conceived to be at a very small distance apart, and then obviously a ray in descending obliquely from one to the other will alter its curvature only by a very slight amount.

Fig. 2.



The fundamental assumptions on which the investigation will be based are the following three:—

(1) It is assumed that the light at A has a certain velocity, which may be called v_1, and that the light at B, where the air is denser, has a smaller velocity, which may be called v_2.

(2) It is assumed that these velocities are constant for all inclinations of the ray of light; or, in other words, that the velocity of the ray of light is independent of the inclination of the ray to the horizontal strata of the air.

(3) It is assumed that the direction of the light is perpendicular to the wave front, or that a surface taken crossing every ray in a pencil of rays perpendicularly, and then conceived to advance along the course of each ray with the velocity of that ray, will continue to cross every ray perpendicularly.

Now let A B and C D be two successive positions, indefinitely near to each other, of the advancing front of a ray or pencil of light whose direction of advance is indicated by the lines E A and F B, and by the arrows R in the figure, the direction at all points of A B being normal to the plane represented by A B. Let the inclination of A B to the vertical line B H be denoted by θ, which will then also denote the inclination of the ray to the horizon. Let the thickness of the lamina of air from M N to O P be denoted by λ, or let B H in the figure be denoted by λ.

The lengths A C and B D have to one another the same ratio as the velocities of light at A and B respectively; or

$$AC : BD :: v_1 : v_2.$$

If A B and C D be produced till they meet in G, the length G A is the radius of curvature of the ray at A. Let this radius be denoted by r. Then, since A B is $=\lambda \sec \theta$, we have obviously

$$v_1 - v_2 : v_1 :: \lambda \sec \theta : r.$$

Hence curvature or $$\frac{1}{r} = \frac{v_1 - v_2}{v_1 \lambda} . \cos \theta,$$

or curvature $\propto \cos \theta$; which shows that the curvature is a maximum when $\theta = 0$, that is, when the ray is level, and that the curvature diminishes to zero as the ray becomes vertical.

The result here brought out, $\frac{1}{r} = \frac{v_1 - v_2}{v_1 \lambda} . \cos \theta$, is perfectly in agreement with that arrived at in the previous investigation of Prof. Purser, namely $\frac{1}{r} = \frac{\mu - 1}{\mu \lambda} \sin i$, seeing that $\sin i$ is $= \cos \theta$, and that, according to the undulatory theory of light as confirmed by experimental proofs, it is known that $v_1 : v_2 :: \mu : 1$, so that $\frac{v_1 - v_2}{v_1}$ must be equal to $\frac{\mu - 1}{\mu}$. The new method has however, the advantage of quite clearing away the perplexity involved in the other by the collapse of the reasoning when brought to the extreme case of the level ray. In the new method no such collapse occurs; and, in fact, the new method shows clearly how the real fundamental principle (that of retardation of velocity in the denser medium, on which the bending depends, and which holds good quite as much for level rays as for any others) is allowed in the previous investigation gradually to fade out of the reasoning, till, in the case of the level ray, it has absolutely vanished from the conditions which were taken into account. The previous method, like the modes of considering the subject of atmospheric bending of rays which appear to have been most generally entertained hitherto, took a consequence of the important fundamental principle into account instead of the principle itself (that consequence being the proportionality of sines of angles of incidence and refraction in case of oblique transition of light from one lamina to another of different density); but that consequence happens to be not so general as the principle from which it follows, and to be one which becomes nugatory or non-existent in the case of the level ray.

In concluding, the author wishes to state that it seemed to him rather unlikely that so simple a view of the influence of the atmosphere in effecting the bending of rays of light as that which he has now offered could be quite new. He thought that others better acquainted with the science of light than he is must most probably have entertained the same or similar views. He has therefore made inquiries as to the views which have hitherto been put forward regarding the bending of light in the atmosphere and in other mediums of continuously variable index of refraction, or, as they may be better considered in the present investigation, mediums of continuously varying light-velocity *. Much has been written on the subject in general, and on various particular cases of its application; and views very similar in principle with those here offered appear in various ways to have been entertained, or implied more or less explicitly; but he has not learned of any thing having been taught which has anticipated the treatment of the subject at present offered so as to deprive it altogether of novelty and interest. The subject, he believes, has been very generally considered under imperfect views; and he will think a good result will have ensued if his drawing the attention of the British Association to it will serve to elicit from others notice of the best views that have hitherto either been fully published, or have been entertained or discussed without complete publication.

POSTSCRIPT.—From Professor Clerk Maxwell I have learned that, in December 1851 or 1852, when on a visit to my brother, Sir William Thomson, he had in his

* $\frac{1}{\mu}$ might be called the index of light-velocity.

mind the consideration of the path of rays in a medium of continuously variable index of refraction; that he then thought it easiest to calculate the path of the ray by translating the problem into the emission theory, and treating the ray as a moving body acted on by a force depending on the variation of the index of refraction, and so proceeding by an artifice justifiable on the ground that the emission and undulation theories are mutually equivalent in respect to the *course* of rays when the proper alterations of the hypotheses are made; and that my brother showed him, on the other hand, how easy it is to begin with the right hypothesis by making the velocity inversely proportional to μ, and calculating the change of wave-front.

Professor Maxwell, in 1853, sent to the 'Cambridge and Dublin Mathematical Journal' a problem about the path of a ray in a medium in which

$$\mu = \frac{\mu_0 a^2}{a^2 + r^2},$$

where μ_0 and a are constant, and r is the distance from a fixed point. Such rays, he points out, move in circles. This problem, he mentions, was intended to illustrate the fact that the principal focal length of the crystalline lens of the eye is very much shorter than anatomists calculate it, from the curvature of its surface and the index of refraction of its substance. The reason, he shows, is the increase of density towards the centre of the lens, so that the rays pass nearly tangentially through a place where the density is varying. Also, in the Cambridge Examinations for 1870, Prof. Maxwell set a question about the conditions of a horizontal ray of light having a greater curvature than that of the earth. A great deal, he says, has been written about atmospheric refraction by Bessel, Clairaut, and others; and a question has been set on it in January of every year at Cambridge for several years back, so that the subject has been much discussed in various ways; but, he says, the mode of treatment of the subject in the present paper does not seem to have been anticipated.—J. THOMSON.

On a Phenomenon connected with Diffraction. By T. OGIER WARD, *M.D. Oxon.*

The author has observed that when he stands at sunset on a hill at such a distance from another hill that his shadow reaches its vanishing-point before arriving at it, instead of a shadow there is diffused light, due to diffraction, more or less in extent in proportion to the distance, and that this light does not disappear until the observer has descended 22° into the shadow of the hill. He throws out the supposition that the bright sky 22° round the sun has a similar power to produce diffraction, and asks whether the sun's corona can be merely this diffracted light, and suggests that during the progress of an annular eclipse the unshadowed portions of the earth ought to receive an extra portion of light from the diffracted light surrounding the shadow of the moon.

On the Importance of the Salts of Uranium in Photography.
By Colonel STUART WORTLEY.

The great advantage of obtaining photographic negatives by means of a sensitive emulsion in lieu of using the collodion and bath separately is beginning to be generally recognized by those who take an interest in the advance of scientific photography. The advantages obtained by this method of working are, first, that the condition of one substance alone, viz. the sensitive emulsion, has to be considered; and, secondly, that a greater degree of sensitiveness can be obtained than by the bath process.

In order to obtain this exalted degree of sensitiveness with an emulsion it is necessary, after the formation of a certain amount of bromide of silver, to saturate the emulsion with as much free nitrate of silver as it will hold in solution. This principle has been recognized by all the most advanced workers since the author first drew attention to such conditions being required in a paper read before the London

Photographic Society in June of last year. But one difficulty opposed itself to the obtaining of good results with certainty—the difficulty of controlling the excess of nitrate of silver from lapsing into an over-sensitive state, and thus causing what in photographic *parlance* is called "fog."

To remedy this state of things, and to have the power of producing a sensitive emulsion that shall keep for months in perfect working order, by adding something to the emulsion that shall exercise a controlling power over the free nitrate of silver, was the problem which the author set himself to work out, and he has been fortunate enough to achieve a complete success.

The author had been familiar with the fact that a mixture of the nitrates of silver and uranium in solution would retain for years their sensitiveness to light without their good qualities being in any way impaired; and it occurred to him that the addition of the nitrate of another metal to that of silver in the sensitive bromized emulsion would give us the power which we wanted of being able to keep a large excess of nitrate of silver from the decomposition which apparently resulted in fog.

In order to make an emulsion collodion which shall have an exalted sensitiveness, and which shall retain all its excellencies unimpaired for months, the author has, after forming therein a certain amount of bromide of silver, add the nitrates of silver and uranium together to the emulsion in certain definite proportions. The result is the formation of a highly sensitive mixture in which no change whatever occurs for a period of certainly three months; and this result cannot be obtained by any means other, so far as he is aware, than by the addition of the nitrate of another metal. The author has tried various other nitrates with perfect success, but has selected and recommended the nitrate of uranium as having, on the whole, greater advantages than any other nitrate with which he is acquainted.

This sensitive emulsion is also of very great value for the preparation of sensitive photographic films to be used in a dry state. These films, prepared with a collodion containing bromide and excess of nitrate of silver (the latter being controlled by the presence of nitrate of uranium), can now be prepared with certainty to have a sensitiveness equal to the best wet collodion sensitized in a bath; and the use of nitrate of uranium gives them the extraordinary advantage of retaining their exquisite sensitiveness unimpaired for any reasonable time; and they will bear after light has impressed a picture upon them the delay of months previous to the development of the invisible impression.

It is with the special object of pointing out how important to the cause of science in distant lands such photographic dry plates may become that the author introduced the subject, as he cannot but feel that if naturalists, geologists, and botanists in distant lands can secure records from day to day on sensitive photographic plates which need not be developed till they return from their expedition, a new power will be placed in the hands of scientific travellers of which, he thinks, they will not be slow to avail themselves.

The author is enabled to speak with great confidence on this point, having himself exposed some of these sensitive dry films in the beginning of May of this year, and which have only now (the middle of August) had the latent image developed, and that without any deterioration whatever.

As, moreover, dry films prepared according to the manner the auther has indicated appear to be entirely unaffected by great heat, they will be of value in explorations in tropical countries, where any other known method of photography would be a great difficulty, if not a real impossibility.

On the Velocity of Light in the Chemical Elements, and on their Crystalline Form. By Ch. V. Zenger, *Professor in the Polytechnic School in Prague.*

The theory of vibratory motion is in strict accord with experiment in the case of sound and its propagation. It was from the analogy between light and sound that physicists ascribed the same laws of motion to both, representing their velocities by the same equation,

$$v=\sqrt{\frac{e}{d}},$$

e being the elasticity and d the density of luminous ether; but there were no means of giving a physical and numerical interpretation of the elasticity and density of ether in certain refracting media.

The index of refraction n is, according to the law of Brewster, equal to the tangent of the angle of polarization-maximum β; hence

$$\tan\beta = n = \sqrt{\frac{d}{e}}.$$

Conceiving the luminous phenomena as produced by molecular vibrations, the density of the luminous ether must be represented by the density or distance of atoms (r), or be a function of it, viz.

$$d = f(r).$$

It is a fact, confirmed by various experiments, that by mechanical pressure, by unequal heating, and by other means augmenting or diminishing the distance of atoms, the velocity of light undergoes a sensible change, isotropical refractive media becoming even doubly refracting. This confirms the supposition that the velocity of light is in connexion with the atomic distances.

It is obvious that there can be no great difference of elasticity in the case of a more rapid vibratory motion than heat is; and if we suppose the elasticity of atoms to be the same in both cases for the propagation of light and heat, there can be no essential error in that hypothesis as to the value or amount of elasticity. Supposing, therefore, elasticity of atoms to be proportional to, or identical with, the specific heat for light and heat, we get

$$n = \frac{1}{v} = \sqrt{\frac{f(r)}{s}},$$

where s denotes the specific heat of the chemical element, v the velocity, and n the index of refraction of light.

As to the form of the function r, the simplest supposition may be tried; putting therefore

$$f(r) = r,$$

we have to try the accordance of that supposition with the data of observation in the equation

$$n = \frac{1}{v} = \sqrt{\frac{r}{s}}.$$

According to the law of Dulong and Petit, the product of atomic weight m and of specific heat s is a constant,

$$ms = \mathrm{C}.$$

Hence we get, if w denotes the specific weight,

$$n = \frac{1}{v} = \frac{m^{\frac{2}{3}}}{w^{\frac{1}{6}}(ms)^{\frac{1}{2}}},$$

or

$$n = \frac{1}{v} = \mathrm{C} \,.\, \frac{m^{\frac{2}{3}}}{w^{\frac{1}{6}}}.$$

The specific heats and densities of chemical elements are referred to water as unit, but the atomic weight w commonly to hydrogen as unit.

Dividing, therefore, the atomic weight by the weight of water, $\mathrm{HO}=9$, it is brought to the same unit as the specific heat and the specific weight w.

We obtain thus

$$n = \frac{1}{v} = \frac{\mathrm{C}m^{\frac{2}{3}}}{(9w)^{\frac{1}{6}}},$$

$$\log n = \log \mathrm{C} + \tfrac{1}{6}(4\log m - \log w - \log 9),$$

$$\log n = 0{\cdot}5795202 - 1 + \tfrac{2}{3}\log m - \tfrac{1}{6}\log w.$$

If the crystalline system is not regular, as in case of sulphur, the density must be different in the direction of three axes, and may be calculated by the proportion,

$$\alpha^2 : \beta^2 : \gamma^2 = \left(\frac{m_1}{d_1}\right)^{\frac{1}{3}} : \left(\frac{m_2}{d_2}\right)^{\frac{1}{3}} : \left(\frac{m_3}{d_3}\right)^{\frac{1}{3}},$$

α, β, γ being the indices of refraction, d_1, d_2, d_3 the densities in the direction of the optical axis.

Table of Indices of Refraction of Elements.

	Observed.	Calculated.	Angle of Pol. Max. Observed.	Angle of Pol. Max. Calculated.
Phosphorus......	2·1059	2·1365	67° 36′	64° 55′
Sulphur	2·22145 2·115	2·1404	63 45	64 57
Diamond........	2·46062 2·51125	2·5620	68 1 67 30	68 40
Graphite........	2·04 2·44	2·2776	65 56	66 13
Silicium diamonds	3·736	3·6000		
Boron diamonds	As Carbon-diamond (*Wohler*).	2·5146		
Mercury	5·8 4·953	5·29645	79 18·5	79 26
Silver	3·6868	3·6627	74 49	74 43
Gold	......	4 9450	......	78 34
Copper	2·5265	2·6414	68 24	69 16
Zinc............	3 0645 2·8950	2·7833	71 51	70 14

Crystalline Forms of Elements.

	Observed.	Calculated.	Observed.	Calculated.
Bismuth	87° 40′	88° 7′·9	1 : 1·3035	1 : 1·3208
Antimony	87 35	86 57·3	1 : 1·3068	1 : 1·3327
Tellurium	86 57	87 12·0	1 : 1·3298	1 : 1·3202
Arsenic	85 4	84 30·9	1 : 1·4025	1 : 1·4403
Sulphur	106 58	107 44·0	....	1·21 : 1 : 0·92

HEAT.

Note on a Condition affecting the Spheroidal State of Liquids, and its probable effect on certain Boiler-Explosions. By W. F. BARRETT.

On the General Oceanic Thermal Circulation.
By WILLIAM B. CARPENTER, *M.D., LL.D., F.R.S.*

The object of this communication was to bring under discussion the question whether the difference of Temperature between Polar and Equatorial Seas con-

stitutes a *vera causa* adequate to maintain the Vertical Circulation advocated by the Author. The *facts* of the case, as determined by recent Deep-sea Temperature observations, made for the most part with Thermometers protected against pressure, are as follows:—

1. In high Northern Latitudes the temperature of the *surface* of the Sea, near the border of the Ice-barrier, is but little above 32° F.; and at small depths below the surface, according to the recent observations of Payer and Weyprecht, it falls below 32°. Making allowance for the known influence of pressure upon the thermometers with which temperature-observations at great depths have been made in these regions, there is every reason to believe that—save in cases in which the temperature of the upper stratum may be modified by local causes—there is a progressive descent from 32° to 29° or even lower; so that the average temperature of *the entire column of Polar Water* may be considered to be not above 30°.

2. In lower Latitudes the temperature of the *surface* of the Sea is greatly influenced by Solar radiation; but the *superheating* thus produced does not generally extend in a marked degree much below 100 fathoms. Beneath this is a stratum of which the temperature may be said to range from about 52° to 45° in all but the highest Latitudes; but the depth of this stratum varies considerably, being about 400 fathoms near the Faroe Banks, about 700 fathoms off the coast of Portugal, and 1000 or 1200 fathoms nearer the Equator.

3. Beneath this stratum is a "stratum of intermixture," in which the Thermometer falls rapidly,—sometimes as much as 10° in 200 fathoms; and below this the temperature again becomes more uniform, sinking very gradually from 39° or 38° to 35° or even to 32°, at depths of more than 2000 fathoms, even under the Equator.

4. Thus the Intertropical column may be regarded as consisting of:—(1) a *superheated stratum*, of which the temperature ranges from 84° at the surface to 52° at 200 fathoms; (2) an upper *warm stratum* of (say) 1000 fathoms depth, of which the temperature ranges from 52° to 45°; (3) a *stratum of intermixture* of about 200 fathoms depth, in which the thermometer falls from 45° to 39°; and (4) of a *cold stratum*, occupying the whole of the deeper portion of the great Oceanic basins beneath 1400 fathoms, its temperature falling with increase of depth, so that in its deepest portion the thermometer has been seen as low as 32°. The *average* of the entire column may thus be about 45°.

Now as *Sea*-water progressively diminishes in bulk and increases in specific gravity down to its freezing-point, it is maintained by the Author that, supposing the Polar and Intertropical columns to be equal in height, the excess of weight in the former will produce a lateral pressure at its lower portion, which will occasion an outflow of Polar Water along the floor of the ocean towards the Equator; this deep outflow, by lowering the surface, will produce an indraught of water into the Polar area, which, in its turn, will acquire by cooling the same excess of Specific Gravity, thus producing a continual *downward* movement; whilst, on the other hand, the cold outflow, being subject to the heating influence of the crust of the Earth beneath and of the warmer water above, will be gradually thinned as it passes towards the Equator, so as to lie at a greater and greater depth beneath the surface. As the continual deep outflow of Polar Water will produce a superficial indraught into the Polar area, and must ultimately derive its supply from the surface of the Intertropical sea, there will be a continual movement of the *upper* stratum *from* the Intertropical towards the Polar area; and as the last-arrived Polar Water will always be colder than that which preceded it, the former will take its place beneath the latter, so that there will be a continual *upward* movement of the water in the Intertropical area. Of this upward movement of colder water from below, a very curious indication has lately been obtained in the fact that off the West Coast of Africa the temperature of the Sea at 200 fathoms is about 5° lower over a bottom deep enough to be covered by the Polar outflow, than it is over a bottom of only 700 or 800 fathoms depth.

The doctrine of a *Vertical Circulation* advocated by the Author was long since suggested by Pouillet as the best explanation of the facts then known in regard to Ocean-temperature; but was put aside through the general acceptance of the doctrine of a uniform Deep-sea temperature of 39½° F., which was supposed to have been established by Sir James Ross's observations, and which was adopted and

promulgated by Sir John Herschel. The corrections supplied by more recent and trustworthy observations have afforded a new set of data; on the basis of which it has been argued by the Author that such a Circulation *must* necessarily take place under the conditions above specified, and that it gives an adequate scientific *rationale* for the facts determined by observation.

This view, however, though accepted by Sir John Herschel shortly before his death, has been contested by Mr. James Croll; but his argument is directed, not against the doctrine advocated by the Author, but against a doctrine set up by himself. Instead of regarding the *level* of the Polar and Equatorial columns as the same, and considering what will be the effect of their difference of *gravity*, he estimates the difference of level which would be produced by the elevation of the average temperature of a column of Polar water to the average temperature of a column of Equatorial water of the same height, and then calculates on this basis the gradient which the surface of the sea would possess along the quadrant. This gradient being far smaller than that which experiment has shown to be necessary to produce a *sensible flow* of water over *a solid surface*, it is assumed by Mr. Croll that this difference of level will be constantly maintained, and that the weights of the two columns will remain equal; so that there will be no such disturbance of equilibrium by the constantly renewed action of Polar Cold, as the Author has maintained.

But it appears to him that Mr. Croll, (1) in assuming that such a difference of level will constantly persist, disregards that fundamental principle of Physics which teaches that fluids will always tend to uniformity of level; and that (2) in relying upon experiments which relate to the movement of Water over *solid surfaces*, he commits the grave error of ignoring the fact that, as shown in the semidiurnal passage of the Tide-wave, sensible movements of water *upon water* are producible by a force that bears a far smaller proportion to that of Gravity than that which is assumed by him to be requisite. On the other hand, Mr. Croll does not attempt to show how the almost Polar coldness of the Deep-Sea bottom, even under the Equator, can be constantly maintained, except by a continual flow of Polar water from the Polar to the Equatorial area; nor does he show how it happens that a disturbance of Thermal Equilibrium which must be constantly undergoing renewal can be without its effect in producing such a continual movement of Ocean-Water as takes place in all collections of fluid that are unequally heated. The *primum mobile* of the Circulation advocated by the Author is *Cold*, which, when applied to the *surface*, seems to him precisely the equivalent of *Heat* applied to the *bottom*,—as in the ordinary apparatus for warming buildings by hot water.

If Cold were continuously applied to a portion of the surface of any collection of Water, however large, and the liquid were not warmed again elsewhere, either by conduction or radiation, the effect of such Cold would be to produce movements in the liquid, by which *the whole* of it would be at last reduced to a *low uniform temperature*; when all movement would cease. But if, while Cold is continuously applied at one part, Heat is continuously applied at another, it is submitted that a Vertical Circulation *must* be produced, which will be kept up as long as these antagonistic conditions are maintained.

The Author, not claiming more for himself than the ability to apply the Elementary principles of Physics under the guidance of Educated Common Sense, submits the foregoing to the consideration of the distinguished Mathematicians and Physicists of Section A; who are much better judges than he can be of the soundness of his views, and of the validity of the objections raised by Mr. Croll.

On Recent Estimates of Solar Temperature. *By* JAMES DEWAR, *F.R.S.E.*

After referring to the recent discussion on the temperature of the sun, in which Secchi, Zöllner, Vicare, Deville, and Ericsson have taken part, the author proceeds to group all the known methods of arriving at a knowledge of high temperatures under eight different processes. The following Table gives the names of the physicists who have specially employed each process, together with the principle on which it is founded:—

(1) Guyton and Daniell, Prinsep, &c.—Expansion of Solids and Gases.
(2) Draper.—Refrangibility of Light.
(3) Clement and Desormes, Deville.—Specific Heat.
(4) Becquerel, Siemens.—Thermo-electricity and Electric Conductivity.
(5) Bunsen, Zöllner.—Explosive Power of Gases.
(6) Newton, Waterston, Ericsson, Secchi.—Radiation.
(7) Thomson, Helmholtz.—Mechanical Equivalent of Heat.
(8) Deville Debray.—Dissociation.

After treating of the great disparity of opinion regarding the temperature of the sun, the author proceeds to detail how it is possible, from the known luminous intensity of the sun, to derive a new estimate of solar temperature. This calculation is based on a definite law relating to temperature and luminosity in the case of solids, viz. the total luminous intensity is a parabolic function of the temperature above that temperature where all kinds of luminous rays occur; so that if T is a certain initial temperature, and I its luminous intensity, a a certain increment of temperature, then we have the following relation:—

$$T+n(a)=n^2 I.$$

The temperature T is so high as to include all kinds of luminous rays, viz. 990° C., and the increment a is 46° C. This formula expresses well the results of Draper, and his numbers are used as a first approximation. It results from the above equation that, at a temperature of 2400° C., the total luminous intensity will be 900 times that which it was at 1037° C. Now the temperature of the oxyhydrogen flame does not exceed 2400° C., and we know from Fizeau and Foucault's experiments that sunlight has 150 times the luminous intensity of the lime-light; so that we only require to calculate at what temperature this intensity is reached in order to get the solar temperature. This temperature is 16000° C., in round numbers. Enormously high temperatures are not required, therefore, to produce great luminous intensities, and the temperature of the sun need not, at least, exceed the above number. Sir William Thomson, in his celebrated article, "On the Age of the Sun's Heat," says, "It is almost certain that the sun's mean temperature is even now as high as 14000° C.;" and this is the estimate with which the luminous intensity calculation agrees well.

On the Temperature of the Electric Spark. By JAMES DEWAR, *F.R.S.E.*

The author begins this paper by calculating the highest hypothetical temperature that could be produced by the chemical combination of the most energetic elements if all the heat evolved could be thrown into the product. This would not exceed 19500° C. in the case of silica, and 15000° C. in the oxides of aluminium and magnesium; and these are the highest results. The estimation of the temperature of the electric spark is based on the thermal value of each spark, together with the volume of the same. The methods of observing these quantities are fully detailed in the memoir. The general result may be stated thus, the temperature of the electric spark used in the experiments ranged between 10000° C. and 15000° C.

On the Stresses produced in an Elastic Solid by Inequalities of Temperature. By J. HOPKINSON, *D.Sc.*

Since the equations of equilibrium and the equations connecting strains and stresses in an elastic solid are both linear, the principle of superposition holds; and we may consider the effect of each cause tending to produce stress as if none other existed, and finally add the result of the separate causes to obtain the effect of all acting together.

It is found that the effect of unequal heating is to subtract from the components of lateral force X, Y, Z, at any point, terms $\gamma\frac{d\tau}{dx}, \gamma\frac{d\tau}{dy}, \gamma\frac{d\tau}{dz}$, where γ is a constant

and τ is the temperature, and consequently that in the case of equilibrium of temperature, *i. e.* where $\nabla^2\tau=0$, the known results,

$$\nabla^2\theta=\rho\frac{d^2\theta}{dt^2},$$

$$\nabla^2\nabla^2 u=0,$$

where θ is the dilation at any point, ρ the density, and u the displacement parallel to the axis of x, are still true; in fact τ appears as part of the potential of external forces.

In the case of a spherical shell, the interior of which is maintained at one constant temperature and the exterior at another, it is found that the stresses are independent of the thickness of the envelope, and that the greater liability of thick vessels to break where the temperature is maintained different in the two surfaces is due to the fact that the thickness of the vessel makes it possible to maintain a greater difference between the surfaces, whilst the general temperatures of the media within and without remain the same as for the thin vessel. In fact the greater safety of a thin vessel lies in its greater conducting-power, and not in the mechanical properties of its form.

The principle of superposition may be applied by integration to the case of the solidification of a fluid sphere in shells beginning at the outside, the effect of the solidification of each infinitely thin shell being calculated, and the strains produced by each added together as an integral.

Electricity and Magnetism.

On Double Neutral Points in Thermoelectric Currents.
By Prof. P. G. Tait, *F.R.S.E.*

On the Use of Electromagnetic instead of Electrostatic Induction in Cable-Signalling. By G. K. Winter, *F.R.A.S., Telegraph Engineer, Madras Railway.*

The experiments on this subject were made by the author in ignorance of the contents of Mr. Varley's specification of 1862. The sending-apparatus being the same as that now in use, the currents from the cable were made to pass through a long, fine, primary wire of an induction-coil, and the induced currents in the secondary wire were used for working the receiving-instrument. In long submarine cables the receiving-instrument was a Thomson's galvanometer; but the siphon recorder might also be used. The signals obtained in this way were steadier, and the elements of the letters more distinctly formed than with the condenser or electrostatic method. On short submarine cables and land-lines, on which Morse's instruments are used, this method, though requiring more battery-power than that now in use, and necessitating the use of a polarized relay, would almost entirely prevent the delays caused by earth-currents during magnetic storms; and on long cables this method, while, equally with the condenser method, rendering earth-currents harmless as far as signalling is concerned, would, besides, cause the cable to be only dynamically instead of statically charged by them, and the danger of damage to the insulator to be at least halved thereby.

Since the paper was read, the author has been informed by Mr. C. F. Varley that the induction-coil was tried by him as early as 1861, on the Dunwich and Zanvoort cable. In 1862 he tried it on the Dunwich and Zanvoort and the Lowestoft and Zanvoort cables, in one circuit of about 1000 nauts; also in 1865 upon the Atlantic cable, on board the 'Great Eastern,' besides many times on his artificial cable.

Meteorology.

On Greek Meteorology. By the Rev. H. A. Boys.

Athens, the only place in Greece where, to the best of the author's knowledge, a meteorological register is regularly kept, is by no means a representative station, being more bracing and dry, hotter in summer, colder in winter than any other place at the same elevation in the kingdom. Patras, where the author, under considerable difficulties, has with tolerable regularity for nearly two years conducted observations of temperature, rainfall, barometer, hygrometer, wind, clouds, and earthquakes, lies on the shore of a gulf open to the west, and more or less shut in by mountains on the remaining sides. Its climate is mild, soft, and relaxing, cooler in summer, hotter in winter than Athens. Standing just to one side of the draught through the narrow entrance of the Gulf of Corinth, it has little variety in the direction of the winds, which nearly always turn the weathercocks E. or W.

But of those winds whose direction is more or less E., there are three distinct kinds:—*First*, a real N.E., which blows in early spring and in summer for ten or even fifteen days together, dropping at night, which brings brilliantly clear, dry, cold weather in February and March, and brilliantly clear, dry, hot weather in the summer time; it covers the pools with a film of ice in winter, and makes even well-seasoned wood warp and crack in summer. *Second*, an apparently E. wind, which originally proceeds from Africa, and blows occasionally from October to June in gales which continue 70 or 80 hours; it is charged with impalpable sand, hiding the sun behind a grey haze, is very violent and hot, and painfully dry, bringing temperature up to 77° even in March. *Third*, a local wind off a mountain near the town, which sweeps down, at night usually, in brief and furious squalls.

The Sirocco, a warm, damp, S. or S.W. wind, brings heavy autumn and winter rains.

The W. wind, which divides with that first mentioned the greater part of the year, is not remarkable in any way, but brings beautiful weather at almost any time.

The Mistrale, a fresh N.W. wind, blows in the summer time after rain in the Adriatic, bringing coolness and moisture when most needed.

Rainfall.—That in Patras differs very much from that in Athens, Patras having by a great deal the larger quantity; and the times at which the rain falls in the two places have no more than a very general agreement. It is best to consider the year's rain from July to June, and so to avoid cutting the rainy season in two, as would be done by dividing the year between December and January.

It is hazardous to attempt general rules from only two years' experience; but the author believes the following will usually hold good:—

July. No rain.

August. A few light showers; perhaps a heavy one.

September. At least one heavy thunder-storm.

For the next four months frequent thunder-storms with heavy rain.

A spell of fine weather in February and March, followed by unsettled weather, with light rains, until the end of April, after which continuous fine weather may be expected, relieved rather than interrupted by a few short though perhaps heavy showers.

In the wettest months a long-continued drizzly rain is a rare occurrence; it comes generally in short heavy showers, between which the sun shines brightly, and the roads, where good, dry up directly.

Temperature.—The author is inclined to estimate the average maxima and minima for the several months as follows:—

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
	°	°	°	°	°	°	°	°	°	°	°	°
Average shade, maximum (Fahr.)	56	56	60	68	76	83	90	89	80	72	66	57
„ „ minimum	40	40	44	50	56	62	69	68	62	55	50	42

TABLE OF TEMPERATURE.	1870. November.	1870. December.	1871. January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
Average maximum temperature......	68·3	60·3	57·1	56·3	61·7	71	76·9	83	90·7	89·8	82·3	73·1	65·2	54·7
Greatest maximum temperature......	75	70	64	62	76	78	88	92	99	96	88	85	73	68
Least maximum temperature......	58	54	49	47	49	62	70	77	83	80	77	64	58	44
Average minimum temperature......	49	44	40·2	40·6	44·2	51·3	56·8	63·4	69·5	68·7	64·1	57·3	51·4	41·7
Greatest minimum temperature......	59	50	49	49	58	57	69·5	67	74	72	70	70·5	59	56
Least minimum temperature......	40	35	32	30	30	43	47	58	64	59	58	47·5	49·5	31

RAINFALL TABLE.		Total fall.	Greatest fall in 24 hours.	Date of that fall.	Number of days on which ·01 or more fell.	Number of days on which ·50 or more fell.	Number of days on which 1·00 or more fell.
1870.	October	1·93	·66	11	7	2	
	November	1·73	·46	9	6		
	December	7·97	1·41	22	22	6	2
1871.	January	7·26	·96	2	18	7	
	February............	2·05	·74	11	8	1	
	March............	1·33	·44	23	7		
	April	·04	·02	2	3		
	May............	·16	·08	28	3		
	June	1·00	·52	28	3		
	July............						
	August............	·17	·09	29	2		
	September	2·00	2·00	13	1	1	1
	October	6·57	1·39	12	11	6	2
	November	9·86	1·31	13	18	9	4
	December	5·96	1·65	15	15	3	2

Ice is rarely seen in Patras, and snow very seldom. Geraniums continue to flower all the winter. But all the winter there is an horizon of snow-capped mountain to the E. half of the compass, which snow is not entirely gone in the middle of July. The heat is great in July and August: last summer there were twenty days running when the maximum was never less than 90° nor the minimum than 70°. For further particulars see Tables.

Clouds.—In the year 1871 there were

29	days on which	no clouds of any sort were seen.
113	„ „	no clouds were seen excepting those which clung about the mountains—days, that is, of uninterrupted sunshine.
182	„ „	clouds were seen in the sky, most of which would be counted as decidedly fine days in England.
41	„ „	the sky was entirely overclouded, so that no blue sky was seen all day long. Thirty-five of these were in January, February, November, and December.

The extreme clearness of the atmosphere deserves attention. A mountain in the island of Cephalonia, 5300 feet high, forms the western horizon, and is visible certainly half the days of the year. So is the Parnassidi range (8000 feet), distant forty miles; and this, when white with snow, is discerned by moonlight. The nearer mountains, ten, fifteen, and twenty miles away, are frequently quite distinctly seen by moonlight without the aid of snow.

Earthquakes are disagreeably common. The author has felt about thirty himself, none of which have done more serious damage than to bring down flakes of plaster. Patras was once entirely destroyed, 540 A.D; but since then the severe shocks have been confined to the shores of the Gulf of Corinth and to the islands of Zante, Cephalonia, Ithaca, and Leucadia.

The author has seen two brilliant AURORAS (October 25, 1870, and February 4, 1872), both of a deep red colour.

On the Advantages of keeping Records of Physical Phenomena connected with Thunder-storms. By W. DE FONVIELLE.

The author begins by referring to the importance of the records of luminous meteors made by the Association, and which have given rise to a great science, the future influence of which on astronomy it is impossible to determine. After having reviewed the work of the Committee for Luminous Meteors, he shows that thunder-storm phenomena are practically far more interesting for us, as being more intimately connected with our personal welfare and security. Only in few disconnected cases do falling stars produce fatal results, while thunder-storms may have an important influence on our property, our health, and our lives. Captive balloons are spoken of by Arago as tending to enlarge the system of protection inaugurated by Dr. Franklin, so that an immense field may be said to be opened for inventions in this direction.

The author showed, by quoting his correspondence, that in this very land the efficiency of lightning-conductors had been questioned, and that in Manchester a conference, held on the occasion of Kersall Church being struck, had arrived at the conclusion that lightning-conductors were worse than useless.

The author referred to the use of the electric telegraph for giving warning to shipping, as practised by the Board of Trade. He alluded also to the steps taken by the French Government for having maps drawn of the course followed by thunder-storms. The author showed that, if the question is limited to the observation of phenomena when places are struck by lightning, it is of great importance and magnitude. Quoting several newspapers, the author finds that not less than five or six cases of great scientific interest had occurred within a month in the county of Sussex, all of these being lost for science and forgotten for ever, if not properly recorded. He is advocating no novelty, as a Committee of the French Institute had officially advised the French Government in 1823 to establish a record of these cases, where a building had been struck by lightning when supplied with a lightning-conductor. He explained how prevalent superstitions had pre-

vented the French Government for a long while from giving force to the advice given by the French academicians. When these obstacles were partially removed the opportunity was lost for establishing it, and the suggestion quite forgotten. He thinks that the French Government of 1872 will take a more intelligent view of the question, especially if the British Association encourages them in doing so, by establishing some definite organization for the purpose, as he is himself a living proof of the interest felt now by the French Government in these matters, having been sent to England in order to report on the late thunder-storms which had been so remarkable. Would it not be in some respects unbecoming of a great nation like England, whose power has been unchecked, to take no interest in these casualties which are attracting the notice of a foreign people emerging from so many calamities?

On a Periodicity in the Frequency of Cyclones in the Indian Ocean south of the Equator. By Charles Meldrum (*Mauritius Observatory*).

One of the objects for which the Meteorological Society of Mauritius was established in 1851, was to obtain extracts from the Meteorological Registers of vessels visiting the harbour of Port Louis, especially of such vessels as had experienced bad weather in the Indian Ocean.

Accordingly clerks were employed to copy all the log-books that could be procured.

In 1853 the system of registration was remodelled. Instead of having the observations contained in each log-book recorded separately, all the observations in all the log-books for the same day were entered on the same page.

As this system has been conducted without interruption to the present time, the Society has now a large collection of observations showing more or less the state of the winds and weather over the frequented parts of the Indian Ocean, in the form of a daily journal, during the last nineteen years; so that a person may find at once what weather prevailed on any day, or in any year, during that period.

Together with the years 1851–52, therefore, during which the registers were differently kept, we have twenty-one years' continuous observation from the meridian of Greenwich to 120° E., and from 23° N. to 45° S.

Adding to the information obtained by the Society throughout these twenty-one years, numerous observations collected by several persons for the previous four years (1847–50), we have a more or less complete record of all, or very nearly all, the cyclones which have taken place in the Southern Indian Ocean during the last twenty-five years; for Mauritius is so much in the track of these cyclones, and so much frequented by vessels in distress, and by others trading between the Colony and England, India, and Australia, that it is scarcely possible for any violent hurricane to happen without being noticed.

Taking now, for the present, the area comprised between the equator and the parallel of 25° S., and the meridians of 40° and 110° E., and examining a Table of the cyclones that have occurred there from 1847 to 1872, it is found that some years have been remarkable for a frequency, and others for a comparative absence of cyclones.

The five years 1847–51 were characterized by cyclone-frequency. Then came a period of comparative calm (1852–57), which was followed by six years (1858–63) remarkable for cyclones. The next five years (1864–68) showed a considerable decrease; and since 1869 there has been an increase, until, for the present year (1872), the number of cyclones is already (28th June) greater than in any year since 1861.

What has now been said is not only borne out by the records of the Meteorological Society, which give detailed accounts of the hurricanes, but also, I have little doubt, by the books of the Docks and Marine Establishments. Especially in 1847 and 1848, and again in 1860–63, the harbour of Port Louis was at times crowded with disabled ships; whereas in the years 1855–57 and 1866–68 there were very few.

It will be seen that these years correspond pretty closely with the maxima and minima epochs of sun-spots.

For the present, I wish merely to call attention to the subject, in order that the connexion which I think exists between sun-spot-frequency and cyclone-frequency may be either verified or refuted by past or future observation. It appears to me that there is more than a mere coincidence as to time. There are *three* maxima and two minima epochs of cyclone-frequency corresponding nearly, if not entirely, with similar sun-spot epochs.

To examine the matter fully, it would be necessary not only to know the *number* of cyclones in each year, but also the extent and duration of each, and the force of the wind. If we could thus get an expression for the annual amount of cyclonic energy, and could show that it varied directly as the amount of sun-spots, a connexion would be established. One violent hurricane, which lasted ten days and passed over thousands of miles, might have more *value* than half a dozen smaller and short-lived ones. However, having traced a large number of the cyclones in question, I have no doubt that the years of greatest cyclone-frequency were generally, if not always, the years of greatest cyclone-energy; and that the number of cyclones in a year is a fair expression of the cyclonic activity for that year.

Now, taking the maxima and minima epochs of the sun-spot period and one year on each side of them, and comparing the number of cyclones in these three-year periods, we get the following results:—

	Years.	Number of Cyclones in each year.	Total number of Cyclones.
Maxima	1847	4	15
	1848	6	
	1849	5	
Minima	1855	4	8
	1856	1	
	1857	3	
Maxima	1859	5	21
	1860	8	
	1861	8	
Minima	1866	5	9
	1867	2	
	1868	2	
Maxima	1870	3	14
	1871	4	
	1872	7	

Taking two years on each side of the solar-spot epochs, we get:—

	Years.	Number of Cyclones.	Total number.
Minima	1854	4	15
	1855	3	
	1856	1	
	1857	3	
	1858	4	
Maxima	1858	4	32
	1859	5	
	1860	8	
	1861	8	
	1862	7	
Minima	1865	3	15
	1866	5	
	1867	2	
	1868	2	
	1869	3	

Assuming that we have got a close approximation to the actual number of cyclones, and that the numbers fairly represent cyclonic energy, it is difficult to avoid the conclusion that the above Tables point to a definite law, and that Meteorology, Magnetism, and Solar Physics are closely connected; for what holds good with regard to a large tract of the Indian Ocean, probably holds good with regard to other portions of the earth's surface.

Is it not probable, also, that if there is such a connexion as is here suggested between sun-spots or sun-cyclones (as they have sometimes been called) and earth-cyclones, there is a similar connexion between the sun-spots and cyclones in the other planets?

The Rainfall of Sussex. *By* FREDERICK ERNEST SAWYER, *of Brighton.*

The county of Sussex is divided by the South Downs into two meteorological districts—the *coast* district, which has a small rainfall and an equable climate, and the *Weald*, which has a much greater rainfall and an extreme climate.

The causes of the increased rainfall in the Weald of Sussex are threefold: first, the *Downs*, which attract and condense the vapour in the rain-clouds which pass over them, causing it to fall in the Weald as rain; secondly, the *forests*, which break the wind and assist in condensing vapour, the cutting-down of the Wealden forests for fuel, when iron was manufactured in the county, having, however, diminished the rainfall in some parts; and, thirdly, the *rivers*, the beds of which form a path, up which rain-storms, and particularly thunder-storms, pass from the coast into the Weald, and also by condensation produce "tidal showers."

The average coast rainfall is about 25 to 26 inches, whilst that of the Weald is nearly 33 inches. The greatest rainfall in the county is at Lynch, near Midhurst, the average there being about 38 or 39 inches. The least rainfall is at Pevensey, where the mean of thirty years was 24·07 inches.

The comparison of the totals of rainfall on both sides of the Downs shows an increase in the totals in the Weald of from 20 to 50 per cent., owing to their influence. At Worthing, on the coast, the mean of three years ending 1871 was 23·88 inches; and at Steyning, in the Weald, it was 34·25 inches, or very nearly 50 per cent. more.

The greatest rainfall recorded in the county is 54·20 inches in 1852 at West Dean, the least at Pevensey in 1858, 13·11 inches. There does not appear to be much difference in the seasonal distribution of rain in various parts of the county.

The low districts round Pulboro', Arundel, Bramber, Henfield, and Lewes become inundated after heavy rains. Such inundations occurred in 1810, 1821, 1828, 1839, and 1847. Severe droughts occurred in 1834, 1847, and 1852.

There is only one rainfall proverb peculiar to the county:—

"When Wolsonbury has a cap,
Hurstpierpoint will have a drap."

Wolsonbury Hill is a summit in the Downs, near Clayton; and when enveloped in clouds, rain may be expected at Hurstpierpoint.

ACOUSTICS.

On Musical Beats and Resultant Tones. *By* RUDOLF KÖNIG.

On the Human Voice as a Musical Instrument. *By* G. VANDELEUR LEE.

INSTRUMENTS.

On the Mensurator, a new Instrument for the Solution of Triangles. *By* W. MARSHAM ADAMS.

The Mensurator is an instrument by which triangles may be solved; that is to say, when the necessary data are given, the instrument may be set according to them, and the values of the other parts read off.

The author illustrated the use of the instrument by numerous examples.

On a new Hygrometer. *By* GEORGE DINES.

The peculiarity of this instrument is, that the use of ether is altogether dispensed with, water only of a lower temperature than the dew-point being required: this is placed in a small reservoir. By turning a tap, the water is allowed to pass through a closed vessel covered with THIN polished metal or black glass. As soon as the dew appears upon the surface of the metal or glass, the flow of the water must be stopped; and a thermometer, the bulb of which is enclosed in the vessel, shows the temperature of the dew-point.

Using this instrument side by side with the dry- and wet-bulb thermometers, the author of the paper has come to the conclusion that (whatever Tables may be used) the latter can never be depended upon as giving more than an approximation to the dew-point. He also describes the aqueous vapour in the atmosphere as badly mixed; and that masses of air very differently charged with moisture are rolling over the surface of the earth in the same manner as the clouds above, the difference being that they are invisible.

On a Nautical Photometer. *By* J. HOPKINSON, *D.Sc.*

The photometers hitherto used for viewing distant lights, too faint for comparison with a standard candle, depend on the absorption of light by a coloured medium till the light is no longer visible. These photometers are defective:—1st, as they do not give the true factor by which the light is diminished in intensity; 2nd, the absorbing medium is arbitrary, and must be arbitrarily defined; 3rd, the effects on red and white lights are not comparable.

The photometer suggested consists of two suitably mounted Nicol's prisms, which can be turned about a common axis till the light is eclipsed. If x be the angle between the polarizing planes of the prisms, the light must be diminished $\frac{m\cos^2 x}{2}$ times to render it invisible, where m is a constant near unity depending on the reflection at the faces of the prisms.

Nouveau Thermomètre destiné à prendre les Températures de la Surface des Eaux Marines ou Fluviales. *Par le* Docteur JANSSEN.

J'ai l'honneur de présenter au meeting un thermomètre d'un nouveau modèle, destiné à prendre la température de la surface de la mer ou des fleuves.

Cet instrument dont j'ai déjà publié une description dans les bulletins de la Société Météorologique de France, le 3 Décembre 1867, a été employé depuis par un grand nombre d'observateurs et a donné des résultats très-satisfaisants, qui permettent de le considérer comme définitivement acquis à la science.

La disposition nouvelle de cet instrument consiste en ce que le réservoir est placé au milieu d'un pinceau de fils de chanvre. Ce pinceau est fixé à la garniture de bois ou de cuivre du thermomètre; il porte à sa partie supérieure une virole de plomb. Lorsque l'instrument est jeté à l'eau, la virole de plomb l'entrainant, il y pénètre rapidement et verticalement; les fils de chanvre s'écartent aussitôt et le réservoir thermométrique se trouve alors en contact avec le liquide, dont il prend la température. En quelques secondes l'équilibre est atteint et on peut retirer le

thermomètre au moyen de son cordon. Aussitôt que l'instrument sort de l'eau les fils se réunissent, entourent le réservoir et conservent par capillarité une quantité assez considérable du liquide dont on voulait obtenir la température. La présence de ce liquide autour du réservoir permet de faire tout à son aise la lecture de l'échelle, car je me suis assuré par des expériences multipliées que l'évaporation à la surface du pinceau, même en présence du soleil et dans un air très-sec, est impuissante à faire varier la température du réservoir avant un temps triple ou quadruple de celui qui est nécessaire à la lecture.

Voici une expérience qui montre avec quelle lenteur le nouveau thermomètre perd la température du bain dans lequel on l'a plongé.

La température de l'eau était de 19° centigrade.

Au soleil un thermomètre ordinaire marquait 37°.

Le thermomètre *à pinceau* fut plongé dans l'eau, marqua bientôt 19°, fut retiré et exposé au soleil. Or, après

30 secondes	il marquait		19°·0	180 secondes	il marquait		19°·15
60	”	”	19·0	210	”	”	19·2
90	”	”	19·0	270	”	”	19·3
120	”	”	19·0	300	”	”	19·4
150	”	”	19·1	360	”	”	19·5

Le temps nécessaire pour retirer le thermomètre de l'eau et en faire la lecture n'est jamais supérieur à 15 secondes. Dans l'expérience rapportée le thermomètre était resté à 19° pendant 120 secondes; c'est 8 fois plus de temps qu'il n'était nécessaire à la lecture.

Températures de la surface de la mer prises par M. Giraud, de Marseilles à Alexandrie.

Dates.		Température de la mer donnée		Latitude Nord.	Long. Est de Paris.
		Par le thermomètre à pinceau.	Par le seau.		
Février.					
19	9ʰ soir....	14°·2	14°·2	° ′	° ′
20	Midi	14·2	14·2	41 15	6 46 E.
	3ʰ......	14·2	14·2		
	6ʰ......	14·2	14·2		
	Minuit ..	14·3	14·3		
	6ʰ......	14·5			
	9ʰ......	14·5	14·5	38 53	11 44
21	Midi	14·5	14·5		
	3ʰ......	14·5	14·5		
	6ʰ......	14·5	14·5		
	Minuit ..	”	”		
	6ʰ......	14·8	14·8		
	9ʰ......	14·8	14·8	37 02	16 16
22	Midi	14·8	14·8		
	3ʰ......	14·8	14·8		
	6ʰ......	14·8	14·8		
	9ʰ......	”	”		
	Minuit ..	”	”		
	6ʰ......	15·0	15·0		
	9ʰ......	15·5	15·5		
* 23	Midi	15·8	15·8	35 02	21 10

* M. Giraud a fait plusieurs centaines d'observations présentant le même accord. Les différences ne s'élèvent jamais à plus de $\frac{1}{10}$ de degré.

C'est à l'occasion des travaux que j'ai exécutés à Santorin en 1867, que j'ai imaginé ce thermomètre pour prendre la température de l'eau de la mer près du volcan alors en activité.

Je m'en suis servi dans un voyage aux Açores en 1867, depuis Lisbonne jusqu'à St. Michel.

Je l'ai également employé dans mes deux voyages aux Indes en 1868 et 1871.

Or j'ai constamment contrôlé les indications du thermomètre à pinceau en prenant les températures par la méthode ordinaire, qui consiste, comme on sait, à puiser directement dans la mer un seau d'eau dans lequel on place un thermomètre. Les deux méthodes se sont toujours accordées à $\frac{1}{10}$ de degré quand on opérait avec le soin nécessaire.

À ma demande, M. Giraud, officier de marine français, a bien voulu prendre des températures de la Méditerranée pendant plusieurs voyages de Marseille à Alexandrie. Cet officier avait aussi le soin de contrôler les indications du thermomètre à pinceau jeté à la mer par celles que le même instrument dépouillé de son pinceau donnait dans un seau d'eau puisé au même instant.

On donne un fragment de ses résultats, p. 60.

En résumé, le thermomètre à pinceau à tres-bien soutenu de nombreuses épreuves depuis cinq années, et on peut le considérer comme un instrument acquis à la science.

On en construit beaucoup en France.

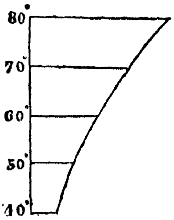
On the Temperature-correction of an Aneroid. By JOHN PHILLIPS, *M.A. and Hon. D.C.L. Oxon., F.R.S., Professor of Geology in the University of Oxford.*

Few instruments invented in modern days have found a more ready and general acceptance for ordinary observations of atmospheric pressure than the Aneroid; but for accurate weighing of the column of air it is not to be trusted without careful precautions, and a preliminary study of the particular instrument employed. The object of this communication is to explain a method by which an instrument which has been in frequent use for nine years, and is liable to enormous variation of reading by change of temperature, has been made to give accurate results.

The instrument has a diameter of 1·9 inch, and weighs 1560 grains. It is quick and firm in its indications while kept in the same position and at the same temperature; but the reading is reduced if the position be changed from horizontal to vertical, and by any, however small, elevation of temperature. It has suffered many shocks, but is entirely uninjured by these and other misfortunes. Though divided only to $\frac{1}{20}$ inch, its indications can be recorded with entire confidence to $\frac{1}{200}$, and are, in fact, by a peculiar method of reading, written down by estimation to $\frac{1}{1000}$. Its *scale* is correct for a range of 24 to 31 inches.

Held in the warm hand, or exposed to sunshine, the index turns sensibly to the left. Heated from 40° to 80°, the deviation exceeds three tenths of the barometric inch. By employing a hot closet the effect is augmented enormously, so that for one degree at 100° Fahr. the index retreats about ·020 inch.

After numerous and often-repeated comparisons with a standard barometer, at different atmospheric pressures and temperatures, the following summary of observed differences or corrections (ϵ) to be applied to this aneroid, so as to make its indications agree with the mercurial instrument, as read at the same time, was adopted as a basis for calculation. The corrections are additive.



Temperature Fahr.	Correction. ϵ.
80	0·420
70	0·300
60	0·200
50	0·130
40	0·080

These numbers, examined by differences, indicate a formula whose principal term involves the square of the temperature. If they be projected as ordinates, a curve of parabolic form results, as given above, the vertex being placed somewhere below 40°, where, probably, a curve of contrary flexure would begin. Assuming the curve to be a parabola, $\beta\,\frac{(\tau-n)^2}{1000}=\epsilon$ the correction for temperature, and taking $n=10°$ and $\beta=\cdot0837$, the values of ϵ are given in the third column.

Temp. Fahr.	ϵ Observed.	ϵ Calculated.	Difference.
80°	·420	·410	−·010
70	·300	·301	+·001
60	·200	·209	+·009
50	·130	·134	+·004
40	·080	·075	−·005

A still closer approximation is found by employing a more complete expression for the function of temperature, such as $\frac{a\,\tau \times b\,\tau^2+c\,\tau^3}{1000}$, in which, between 40° and 80°, $a=0$, $b=\cdot03$, $c=\cdot000445$. The resulting corrections appear as under, from 90° to 30°, the utmost limits of probable observation in the British Isles.

Temperature.	$b\tau^2$.	$c\tau^3$.	ϵ Observed.	ϵ Calculated.	Difference.
90°	·243	·324	....	·567	
80	·192	·228	·420	·420	·000
70	·147	·153	·300	·300	·000
60	·108	·096	·204	·200	+·004
50	·075	·056	·130	·131	+·001
40	·048	·028	·080	·076	−·004
30	·027	·012			

A Table constructed in accordance with this formula has been found, by much experience, to give very satisfactory results in measures of terrestrial elevation. The author has also investigated instruments compensated for temperature, and finds in some cases a curve-correction necessary for inequality of scale.

Description of the new Marriotti Barometer. *By* MACNEIL TELFORD.

The Spiral Top. *By* Prof. CH. V. ZENGER.

On a stand of brass, fastened to a board, a screw moves in a vertical direction on the upper end of the stand. The axis of the top, with its conical end, is put in a conical hole worked in the screw, and the other end lies in a similar conical hole on a support fastened to the board vertically and in the same line as the screw.

On the axis of the top is fastened a movable arm, with a screw and ball of brass that can be fastened at different distances from the axis of rotation.

A double ring of brass to span a sheet of paper in it may be fastened on the screw, the plane of the paper being vertical to the axis of the top. The apparatus is then prepared to show the nutation of the axis and precession of the nodes by spinning it. The axis of the top describes a circle on the paper, on which an ellipse evolves, whose length of axis depends on the position of the arm on the axis and the distance of the ball screwed to it. Taking the brass arm with the

ball from the axis, and fastening the spiral wire to it, the top is prepared for another experiment.

In the former experiment a circle is described if the velocity does not change; but the friction and resistance of the air tend to diminish it; and so with a decreasing velocity of rotation the angle of inclination of the top's axis becomes changeable, and instead of a circle, a spiral line is described, with ellipses evolving on it, as is shown by pressing the paper against the axis for a longer time, the paper being covered with a thin layer of soot.

The author tried to bring a top without the brass arm and ball in contact with a spiral line, constructed by a wire bent into a spiral line. The top then began rapidly to move along the spiral line, and, reaching its end, began to follow again the direction of the spiral wire on its inner side, and so on.

This spiral and periodical motion is similar to that of a pendulum on a prescribed or given trace; it is very like that of a cycloidal pendulum, where the motion must be performed on a cycloid.

The disturbing force produces a pressure on the wire, and forces the axis of the top to follow the direction of the spiral curve.

The spiral may be replaced by a curve of any other description.

On the Tangential Balance and a new Saccharometer. *By* Professor Ch. V. Zenger.

Progress of Science.

On the Duty of the British Association with respect to the Distribution of its Funds. *By* Lieut.-Col. A. Strange, *F.R.S.*

The author begins by referring to the Royal Commission on Scientific Instruction and the Advancement of Science, of which the Duke of Devonshire is Chairman, the appointment of which was obtained by the British Association in 1870. Having been examined himself by the Commission, and having been in communication with many of the witnesses who have appeared before it, he is able to say that the following fundamental points are receiving great attention, viz.:—(1) that the objects of scientific teaching and of scientific investigation are distinct, and require for their respective attainment distinct machinery; (2) that the State is bound, in the interests of the community, to maintain Institutions, such as Laboratories and Observatories, for scientific research, apart from teaching; (3) that all State Scientific Institutions and action of every kind should be subject to the direction of a single Minister of State; and (4) that such Minister of State should have the assistance of a permanent paid Consultative Council, composed of eminent men of science. Of these measures he regards the two last (a Minister and Council) as by far the most important.

The paper next proceeds to consider how the Association may further advance the great question of State Scientific Organization. The writer considers that one of the greatest obstacles in the way consists in the imperfect conception which statesmen have formed of the duties of the State with respect to science; and he believes that this is in a great measure due to indiscriminateness in private action and the distribution of private funds. Many great scientific problems have been taken up with the help of such means, only to be laid aside because those means have proved insufficient. The result is a confusion of thought as to what scientific objects should be carried out by the State, and what may properly devolve on private bodies and individuals.

In order to assist in clearing up this confusion, the author proposes that the Association should classify all applications for aid coming before them under two great heads—Public and Private; that they should grant pecuniary aid to the latter only; that they should furnish the Government annually with a list of objects

which they regard as Public, with such advice as to the best mode of attaining them as may seem necessary; and that before each annual meeting they should ascertain from the Government what progress has been made towards the attainment of those objects, publishing the result in their Proceedings.

The author disclaims any wish to bring the Association into collision with the Government. He does not believe the above measures would have that effect; and he sees no other mode of bringing forcibly before the Government, in a practical form, those great wants of science which State resources alone can supply.

He next proposes the following tests by which to distinguish Public Science for the purpose of classification:—(1) Continuity; (2) Probability of Expansion; (3) Unremunerativeness to the individual cultivating it, combined with profit or advantage to the community generally; (4) Costliness. No body is better able to supply such tests with discretion than the British Association.

The author then enumerates some typical examples of private aid injudiciously given to strictly public objects; viz. the Kew Observatory, Rainfall, Sewage, the Map of the Moon, and the Tides.

After pointing out the effect in each of these cases, he then urges that the action now proposed will not chill individual enterprise, which is too fixed a sentiment in the English character to be capable of eradication. He is convinced that ample use will be found for the limited income of the Association after eliminating purely public objects. He admits that such objects will perhaps at first be more or less neglected if abandoned by the Association; but he considers that this inconvenience will be cheaply purchased by the dissemination of sounder views on State Science, to which it cannot fail to lead.

CHEMISTRY.

Address by J. H. GLADSTONE, *Ph.D., F.R.S., President of the Section.*

ONE of my fellow-students in the laboratory of the late Professor Graham began the study of Chemistry because he wanted to be a geologist, and he had read in some Geological Catechism that, in order to be versed in that science, it was necessary, as a preliminary step, to gain a knowledge of Chemistry, Mineralogy, Zoology, Botany, and I know not what besides. My friend became a chemist, and found that enough for the exercise of his faculties. Yet the catechism had truth on its side; for so intertwined are the various branches of observational or experimental research, that a perfect understanding of one can only be obtained through an acquaintance with the whole cycle of knowledge.

Yet, on the other hand, who can survey the whole field even of modern Chemistry? There was a time doubtless, in the recollection of the more venerable of my auditors, when it was not impossible to learn all that chemists had to teach; but now that our "Handbook" has grown so large that it would take a Briareus to carry it, and it requires a small army of abstractors to give the Chemical Society the substance of what is done abroad, we are compelled to become specialists in spite of ourselves. He who studies the general laws of Chemistry may well turn in despair from the ever-growing myriads of transformations among the compounds of carbon. We have agricultural, physiological, and technical chemists; one man builds up new substances, another new formulæ; while some love the rarer metals, and others find their whole soul engrossed by the phenyl compounds.

How is this necessity of specialization to be reconciled with the necessity of general knowledge? By our forming a home for ourselves in some particular region, and becoming intimately conversant with every feature of the locality and their choicest associations, while at the same time we learn the general map of the country, so as to know the relative position and importance of our favourite resort, and to be able (when we desire it) to make excursions elsewhere.

To facilitate this is one of the great objects of the British Association. The

different Sections are like different countries; and, leaving the insular seclusion of our special studies, we can pass from one to the other, and gain the advantages of foreign travel.

From this Chair I must of course regard Chemistry as the centre of the universe, and in speaking of other Sections I must think of them only in their relation to ourselves. There is that rich and ancient country, Section A, which, according to the Annual Report, comprises several provinces, Mathematics, Astronomy, Optics, Heat, Electricity, and Meteorology.

Mathematics and Astronomy.—It was when the idea of exact weights and measures was projected into it that Alchemy was transmuted into Chemistry. As our science has become more refined in its methods its numerical laws have become more and more significant; and it may safely be predicted that the more closely it is allied with general physics, the greater will be the mathematical knowledge demanded of its votary. But till lately the Chemist and the Astronomer seemed far asunder as the heavens and the earth, and none could have foretold that we should now be analyzing the atmospheres of the sun and stars, or throwing light on the chemical composition of planetary nebulæ and the heads of comets. There is in this, too, as in other things, a reciprocal benefit; for we are encouraged to hope that this celestial chemistry will reveal to us elements which have not yet been detected among the constituents of our globe.

Light, Heat, and Electricity.—How intimately are these associated with the chemical force, or rather how easily are these Protean forces transformed into one another! The rays of the sun coming upon our earth are like a chemist entering his laboratory: they start strange decompositions and combinations not only in the vegetable kingdom, but also among inorganic gases and salts; they are absorbed selectively by different bodies which they penetrate, or are refracted, dispersed, and polarized according to the chemical composition and structure of the substance. All this has been the subject recently of much scientific research; and I need scarcely remind you of the beautiful art of photography as one of the results of photo-chemistry, or of the benefits that have arisen from a study of circular polarization, indices of refraction, and especially spectrum-analysis. In regard to the latter, however, I would remark that while the optical examination of the rays emitted by luminous vapours has yielded most brilliant results, there is another kind of spectrum-analysis—that of the rays absorbed by various terrestrial gases, liquids, and solids—which has already borne valuable fruit, and which, as it is far more extensively applicable than the other, may perhaps play a still more important part in the Chemistry of the future. The dispersion of the rays of the spectrum is certainly due to the chemical nature of the body through which they pass; but this is as yet almost unbroken ground waiting for an explorer. As to heat, it has ever been the tool of the chemist; and it would be difficult to overestimate the significance of researches into the specific heat or the melting- and boiling-points of elements and their compounds. The laws of chemical combination have been elucidated lately by thermo-chemical researches; it has been sought to establish a connexion between the absorption or radiation of heat and the complexity of the chemical constitution of the active body; while the power of conducting heat, or of expanding under its influence, offers a promising field of inquiry. As to electrical science, one department of it (Galvanism) is strictly chemical; the electrolytic cell does our work: and indeed we claim half the electric telegraph; for while the needle may oscillate in Section A, the battery belongs to B.

Last in Section A comes Meteorology; and there are chemical questions concerning the constitution of the atmosphere, its changes, and the effect of its occasional constituents upon vegetable and animal life, which merit the deepest attention of the physiologist, philanthropist, and statesman.

If we turn to Section C, there is an outlying province belonging to us—namely, Mineralogy, which lies on the frontiers of Geology. A vast and very promising region is the origin and mode of formation of different minerals: this has attracted some explorers during the past year; but in order to investigate it properly the geologist and the chemist must travel hand in hand. Geology, in demanding of us the analysis of earths and ores, rocks and precious stones, repays us by bringing to our knowledge many a rare element and strange combination.

When we pass from C to D (that is, from the crust of the globe to the organized beings that inhabit and adorn it) we are introduced into new regions of research. When organic chemistry was young, Cuvier said of it, "Dans cette nouvelle magie, le chimiste n'a presque qu'à vouloir: tout peut se changer en tout; tout peut s'extraire de tout;" and though we have now learnt much of the laws by which these magical transformations proceed, they far transcend the dreams of the French philosopher; there is yet no visible limit to the multitude of products to be derived from the vegetable and animal world, and their changes seem to afford boundless scope for chemical ingenuity. The benefit here also is reciprocal; for the physiologist enters by our aid into the wonderful laboratory of the living plant or animal, and learns to estimate the mode of action of different foods and medicines. There have lately been some good researches of this character. The difficulties are great; but the results to be achieved are worthy of any effort.

There may be little intercourse between us and the geographers in E; but we stand in no distant relationship with many of the subjects discussed in F. Economic science embraces the chemical arts, from cookery upwards; such imperial questions as that of the national standards, or the patent laws, interest us greatly; the yield of our corn-fields is increased through our knowledge of the constituents of soils and manures; and upon many of the chemical manufactures depend in no small degree the commerce and the wealth of Britain.

In this most important branch of technical chemistry we need the skill of the mechanician; and this introduces us to Section G. One of the questions of the day will illustrate the connexion between these varied departments of study. Statistics prove that the consumption of coal is now advancing, not at the gradual pace which recent calculations allowed, but at a rapidly accelerating speed; and they make the householder anxious about rising prices, and the political economist about the duration of our coal-fields. It is well known that there is a great waste of fuel throughout the country, as the maximum of heat produced by the combustion is very far from being ever utilized; and it will be for the combined wisdom of the chemist, physicist, and mechanician to devise means for reducing this lavish expenditure, or to indicate other available sources of power.

While this correlation of the natural sciences renders it desirable that the votary of one should have some general acquaintance with the rest, the correlation of all knowledge shows that no education can be complete which ignores the study of nature. A mind fed only on one particular kind of lore, however excellent that kind may be, must fail of proper nourishment. I am not going to say a word against philological studies: I am too fond of them myself for that; and I could wish that the modern languages were taught more, and the classic languages were taught better, than they are at present. What I do contend for is, that chemistry (or some cognate branch of science) should have an honoured place in the education of every English lady and gentleman. I say purposely "an honoured place;" for at present where chemistry is introduced we too often find the idea latent which was expressed by one principal of a lady's college, who told a friend of mine that he was to give the girls a course of pretty experiments, but that she did not expect him to teach them any thing; and we know that when boys repeat chemical experiments at home it is looked upon as an amusement, a philosophical one no doubt, but rather objectionable, inasmuch as they spoil their mother's towels and singe their own eyebrows.

Of course some knowledge of chemistry is indispensable for a large number of our manufacturers, and for the medical profession, while it is extremely valuable to the farmer, the miner, and the engineer. It will also be readily granted that information about the air we breathe, the water we drink, the food we live upon, the fuel we burn, and the various common objects we handle, must be of service to every man. But we are met by the advocates of the old system of education with the remark that the value of school-teaching does not depend so much upon the information given as upon the mental training. This I admit—though it seems to me that if the same training can be secured by two studies, the one of which (like the making of Latin verses) gives no information at all, and the other (like chemical analysis) imparts some useful knowledge, we should prefer the latter. But I hold that, as a means of educating the mental faculties, chemistry, faithfully taught, has

in many respects the advantage over literary studies. There is superabundant scope for the exercise of the memory; the powers of observation are developed by it to a wonderful degree; the reasoning powers may be well disciplined on the philosophy of chemical change, or the application of the laws of Dalton, Mitscherlich, and Avogadro; while the imagination may be cultivated by the attempt to form a conception of the ultimate particles of matter, with their affinities and atomicities, as they act and react upon one another under the control of the physical forces. And I might speak of higher considerations than mere intellectual culture; for surely the works of the Allwise and Bountiful Creator are a more truthful and a purer subject of contemplation for the opening minds of youth, and more in accordance with Christian ideas, than are the crude notions of a past stage of civilization, and the ignorant and gross fancies of a defunct paganism.

There is another requirement in education—the training of the mind to the discovery and recognition of truth. For this purpose philological studies have no fitness; mathematical studies, though peculiarly adapted for it, apply only to cases where demonstrative proof is possible; but the study of physical science is remarkably well fitted for teaching the proper methods of inquiry, and the strict relations between theory and fact. Now the historian, the politician, the mental philosopher, the theologian, or any one else who desires to influence the thoughts of his fellow men, should be in a position to distinguish between truth and error in his own department; and his mind may be well disciplined for this by a study which is less liable to be disturbed by human passions, predilections, or wishes, and where the conclusions are more readily brought to the test of observation or experiment.

Our Government insists on a certain standard of education for all who are allowed to teach in our elementary schools. In those schools which receive no State aid it is only public opinion which can insist that the teacher shall be duly qualified himself. Such bodies as the British Association form this public opinion, and will deserve well of their country if they demand that these masters and mistresses shall know something of the material universe in which they move, and be able to impart to every child such scientific knowledge as shall afford him an interesting subject for thought, give him useful information, and discipline his mental powers.

Among the many services rendered by the monthly reports of the progress of chemistry which the Chemical Society publishes, and the British Association helps to pay for, there is one which is rather salutary than pleasant. They bring prominently before our notice the fact that in the race of original research we are being distanced by foreign chemists. I refer not to the quality of our work, about which opinions will probably differ, but to the quantity, which can be determined by very simple arithmetic. This is a matter of no small importance, not only for the honour of England, but still more for the advancement of science and the welfare of man. From the Physical Chair of this Association last year, a note of warning was uttered in the following words, after a reference to the sad fate of Newton's successors who allowed mathematical science almost to die out of the country:—"If the successors of Davy and Faraday pause to ponder even on *their* achievements, we shall soon be again in the same state of ignominious inferiority." The President of the Chemical Society also, in the last Anniversary Address, drew attention to the diminished activity of Chemical discovery, and to the lamentable fewness of original papers communicated. He traces this chiefly to "the non-recognition of experimental research by our universities," and suggests that in the granting of science-degrees every candidate should be required, as in Germany, to prove his ability for original investigation.

Concurring in this, I would remark that other causes have also been assigned, and other suggestions have been made. There is the small recognition of original research even by our learned Societies—at least such recognition as will come home to the understanding of the general public. It is true the fellowship of the Royal Society is awarded mainly for original discoveries, and there are two or three medals to be disposed of annually; but these distinctions fall to the lot of the seniors in science, often men who are beyond the need of encouragement; and though they doubtless are serviceable as incentives, there is many a beginner in the honourable contest of discovery who is too modest even to hope for the blue

ribbon of science. While the Victoria Cross is awarded to few, every soldier who has borne part in a victory expects his clasp; and so might every man who has won victories over the secrets of nature fairly look for some public recognition. It has been suggested, for instance, that the Royal Society, in addition to the F.R.S., might institute an Associateship, with the letters A.R.S., designed exclusively for those younger men who have shown zeal and ability in original research, but whose discoveries have not been sufficient to entitle them already to the Fellowship. It is suggested, too, that the Chemical Society might give some medal, or diploma, or some similar distinction to those who contribute papers of sufficient merit.

But beyond this is the non-recognition of scientific research by society in general. We can scarcely expect the average enlightened Englishman to be any thing but scared by a graphic formula, or a doubly sesquipedalian word containing two or three compound radicals; but he need not continue to talk of the four elements, or of acids being neutralized by sugar. But, indeed, the so-called educated classes in England are not only supremely ignorant of science; they have scarcely yet arrived at the first stage of improvement—the knowledge of their own ignorance. Then, again, there is the excessive preference of practical inventions over theoretical discoveries—or rather, perhaps, the inability to appreciate any thing but tangible results. Thus a new aniline compound is nothing unless it will dye a pretty colour; if we speak of the discovery of a new metal by the spectroscope, they simply ask, What is it useful for? and the rigorous determination of an atomic weight has for them no meaning, or interest, or beauty. The general appreciation of science must be of gradual growth; yet there are wealthy men who know its value, and who might well become the endowers of research. There are, indeed, at present funds available for the purpose—such as the Government Grant, and the surplus funds of this Association; but the money is given simply to cover actual outlay; and this, though very useful, scarcely meets the case of those young philosophers who have no balance at their bankers, and yet must live. Will not some of these wealthy men endow experimental scholarships, or professorships, in connexion with our colleges, institutions, or learned societies? As an instance of the good that may be effected in this way, may be cited the Fullerian professorships; and as a very recent example, worthy of all honour, may be mentioned the purpose of Mr. J. B. Lawes, not only to continue his elaborate experiments at Rothamsted throughout his lifetime, but to place his laboratory and experimental fields in trust, together with £100,000, so that investigations may be continued in the wider and more scientific questions which the progress of agriculture may suggest.

The Government of our country, through the Science and Art Department, renders good assistance to the teaching of science; and if the recommendations of the Royal Commission on Scientific Instruction and the Advancement of Science be adopted, the introduction of practical examinations for the obtaining of certificates for a superior grade of science-master will certainly foster a spirit of research. It has been generally held that the promotion of research is within the legitimate scope of government; and where, as in the case of Aristotle and Alexander, genius and industry have been sustained by princely munificence, the happiest results have ensued. Yet this question of Government aid is a delicate one: for genius, when put into swaddling clothes, is apt to be stifled by them; and were science to depend on political favour or imperial support, it would be a fatal calamity. Still I think it will be everywhere admitted that science might with propriety be subsidized from the public funds in cases where the results may be expected to confer a direct benefit upon the community, and where the inquiry, either from its expense, its tediousness, its uninteresting character, or the amount of cooperation required, is not likely to be carried out by voluntary effort. The astronomical work which is paid for by Government bears upon navigation, and answers both these requirements; and it is easy to conceive of inquiries in our own science that might equally deserve the assistance of the State. Some of these might also more than repay the outlay, though perhaps the profit would not fall into next year's budget.

I believe that this diminution of original research, which we deplore, is partly due to a cause in which we rejoice—the recent extension of science-teaching. The professorships of chemistry are scarcely more numerous now than they were twenty

years ago, while the calls upon the professor's time in conducting classes or looking over examination papers have greatly augmented. Thus some of the most capable men have been drawn away from the investigation of nature; and in order to afford them sufficient leisure for the purpose, means must be found to multiply the number of the professorships in our various colleges.

While the rudiments of science are being infused into our primary education, now happily becoming national, while physical science is gradually gaining a footing in our secondary and our large public schools, and while it is winning for itself an honoured place at our universities, it is to be hoped that many new investigators will arise, and that British chemists will not fall behind in the upward march of discovery, but will continue hand in hand with their continental brethren thus to serve their own and future generations.

Chemical Nomenclature. *By* Dr. A. Crum Brown.

This communication does not contain a proposal of a new nomenclature or of a new system of nomenclature, but was intended as a contribution to that critical examination of chemical names which, it may be hoped, will lead to the development of a single language, capable of expressing clearly, completely, and shortly the actual relations of substances to one another, and *any* theoretical speculations which are, or may be, entertained by chemists.

Three different kinds of names at present used are considered:—1st. Proper names, *i. e.* names which, merely in virtue of a convention, represent particular substances. 2nd. Names which indicate the *composition* of the substances represented. 3rd. Names which indicate the relation of the substances to others, and which may therefore be called functional names. In a functional nomenclature each substance will have more than one name, as it has more than one relation to other substances; but no confusion need result from this, as each name will be used in its own place, when the relations implied in the name are treated of.

On the Relative Power of Various Substances in preventing Putrefaction and the Development of Protoplasmic and Fungus Life. *By* Dr. F. Crace-Calvert, *F.R.S., F.C.S., &c.*

To carry out this series of experiments, small test-tubes were thoroughly cleansed and heated to dull redness. Into each was placed 26 grammes of a solution of albumen containing one part of white of egg to four parts of pure distilled water, prepared as described in my paper on protoplasmic life. To this was added one thousandth, or ·026 gramme, of each of the substances the action of which I desired to study. The reasons why I employed one part in a thousand are twofold:—first, the employment of larger proportions would, in some instances, have coagulated the albumen; secondly, it would have increased the difficulty of determining the relative powers of the most efficacious antiseptics in preventing the development of the germs of putrefaction or decay, as the period of time required would have extended over to twelve months. A drop was taken from each of the tubes, and examined under a microscope having a magnifying-power of 800 diameters. This operation was repeated daily for thirty-nine days, and from time to time for eighty days. The tubes were kept in a room the temperature of which did not vary more than 3°, namely from 12°·5 C. to 15°·5 C., during the time these experiments lasted.

In order to appreciate the influence of the antiseptics used, I examined two solutions of pure albumen, one of which was kept in the laboratory, the other in the open air.

A marked difference was observed in the result, the solution kept outside becoming impregnated with animal life in less than half the time required by the other, while as many vibrios were developed in six days in the solution outside, as were developed in thirty days in the one in the laboratory.

A summary of the results of the experiments is given in the following Table, in which the substances are grouped according to their chemical nature.

Substances used.	Days required for development of Fungi at 15° C.	Days required for development of Vibrios at 15° C.	Days required for due development of putrid odours in albumen kept at 26° C.
1. *Standard Solutions.*			
Albumen kept in laboratory for comparison	18	12	16
Albumen exposed outside laboratory	None	5	
2. *Acids.*			
Sulphurous acid	21	11	45
Sulphuric acid	9	9	16
Nitric acid	10	10	16
Arsenious acid	18	22	None
Acetic acid	9	30	None
Prussic acid	None	9	35
3. *Alkalies.*			
Caustic soda	18	24	72
Caustic potash	16	26	85
Caustic ammonia	20	24	26
Caustic lime	None	13	14
4. *Chlorine Compounds.*			
Solution of chlorine	22	7	16
Chloride of sodium	19	14	16
Chloride of calcium	18	7	11
Chloride of aluminium	21	10	16
Chloride of zinc	53	None	38
Bichloride of mercury	81	None	None
Bleaching-powder	16	9	9
Chlorate of potash	19	17	38
5. *Sulphur Compounds.*			
Sulphate of lime	19	9	14
Protosulphate of iron	15	1	16
Bisulphite of lime	18	11	16
Hyposulphite of soda	18	11	11
6. *Phosphates.*			
Phosphate of soda	17	13	16
Phosphate of lime	22	7	16
7.			
Permanganate of potash	22	9	11
8. *Tar Series.*			
Carbolic acid	None	None	None
Cresylic acid	None	None	None
9. *Sulphocarbolates.*			
Sulphocarbolate of potash	17	18	35
Sulphocarbolate of soda	19	18	26
Sulphocarbolate of zinc	17	None	None
10.			
Sulphate of quinine	None	25	None
Picric acid	19	17	26
Pepper	None	8	16
Turpentine	42	14	35
11.			
Charcoal	21	9	None

In comparing the results given in the above Table, the substances can be classed under four distinct heads, viz. those which prevent the development of protoplasmic and fungus life, those which prevent the production of vibrio life, but do not prevent the appearance of fungus life, those which permit the production of vibrio life, but prevent the appearance of fungus life, and those which do not prevent the appearance of either protoplasmic or fungus life.

The first class contains only two substances, carbolic and cresylic acids. In the second class also there are only two compounds, chloride of zinc and bichloride of mercury.

In the third class there are five substances, lime, sulphate of quinine, pepper, turpentine, and prussic acid. In the fourth class is included the remaining twenty-five substances.

The acids, while not preventing the production of vibrios, have a marked tendency to promote the growth of fungi. This is especially noticeable in the case of sulphuric and acetic acids. Alkalies, on the contrary, are not favourable to the production of fungus life, but promote the development of vibrios.

The chlorides of zinc and mercury, while completely preventing the development of animalcules, do not entirely prevent fungus life; but I would call special attention to the interesting and unexpected results obtained in the cases of chlorine and bleaching-powder. When employed in the proportion above stated, they do not prevent the production of vibrio life.

In order to do so they must be employed in excess; and I have ascertained, by a distinct series of experiments, that large quantities of bleaching-powder are then necessary; but the organic matter is also destroyed, its carbon being converted into carbonic acid, and part of its nitrogen liberated.

If, however, the bleaching-powder be not in excess, the animal matter will still readily enter into putrefaction. The assumption on which its employment as a disinfectant has been based, namely that the affinity of the chlorine for hydrogen is so great as to destroy the germs of putrefaction, is erroneous. The next class to which I would call attention is the tar series, which gave no signs of vibrionic or fungus life during eighty days. The results obtained with sulphate of quinine, pepper, and turpentine deserve notice. None of them prevent the development of vibrios, but sulphate of quinine and pepper entirely prevent the appearance of fungi. This fact, together with the remarkable efficacy of sulphate of quinine in intermittent fever, would lead to the supposition that this disease is due to the introduction into the system of fungus-germs; and this is rendered the more probable, if we bear in mind that these fevers are prevalent only in low marshy situations, where vegetable decay abounds, and never appear to any extent in dry climates even in dense populations where ventilation is bad and putrefaction is rife. The results obtained in the case of charcoal show that it possesses no antiseptic properties, but that it prevents the emanation of putrid gases owing to its extraord nary porosity, which condenses the gases, thus bringing them into contact with the oxygen of the atmosphere, which oxidizes and destroys them. The above facts have been confirmed by a second series of experiments.

On the Presence of Albumen in Neutral Fats, and on a New Process for the Manufacture of Stearic and Palmitic Acids, &c. By WILLIAM LANT CARPENTER, *B.A., B.Sc., F.C.S.*

In the International Exhibition of 1871 there were exhibited specimens of very fine stearic acid, made by a new process invented by Professor J. C. A. Bock, of Copenhagen. This process the author had studied practically, and had extended its application to vegetable fats.

The disadvantages of processes hitherto in use for decomposing neutral fats were pointed out. In the lime saponification, either 66 per cent. above the theoretical quantity of lime was required, or else a very high pressure. In the various processes of distillation the waste of material was considerable, and the risk of fire great. Where water alone was used, the high pressure required frequently burst the vessels employed. The inventor of the process under consideration was a scien-

tific man, of high culture, in early years a distinguished surgeon, and till recently medical adviser at the Court of Copenhagen. He believed that all neutral fats were composed of minute globules of fatty matter, each one of which was encased in an envelope of a substance which he termed albumen (in the proportion of 1 to 2 per cent. of the whole fat), the existence of which could be demonstrated by dissolving the fat in ether or benzole, and precipitating the solution with water, when the albuminous matters collected at the plane of junction of the water and the fatty solution. In his opinion, the excess of alkali, or of heat, or of pressure, necessary to decompose a neutral fat, was required to destroy this albumen, with which were associated many of the colouring-matters. By the use of certain oxidizing agents, the envelopes of the globules composing neutral fat could be disintegrated, and subsequently oxidized, so that their specific gravity was increased, and they could then be removed by mere subsidence, leaving the fatty acids comparatively free from colour.

In practice, the tallow, heated to 115° C. in an open vat, is well agitated with 6 per cent. sulphuric acid for a short period, by which the albuminous envelopes are charred and broken up. Water is then added, and the blackened but *still neutral* fat boiled with it. Decomposition of the fat *gradually* takes place, the degree of it being judged of by the mode of crystallization of the fatty acids. When it is complete, the water is run off, and the glycerine which it contains is purified from sulphuric acid by precipitation of the latter with lime, and concentrated for sale. The blackened fatty acids are then subjected to the action of a solution of one or more of the following oxidizing agents—sulphuric, nitric, and hydrochloric acids, bichromate and permanganate of potash, and hypochlorite of lime. The albuminous matters coagulate together, and increase so much in specific gravity, that they subside in a few hours, leaving the fatty acids of a pale brown colour. These acids are then washed, crystallized, and subjected to cold and hot hydraulic pressing in the usual manner. The products are a stearic acid whiter, harder, and greater in quantity per ton of tallow than that obtained by any other method, and elaïdic acid superior to that made in any other way. The author of the paper was engaged in extending the invention to vegetable fats. He illustrated the paper with specimens from Copenhagen (sent expressly for the Meeting) and from his own factory.

On the Mode of Collection of Samples of Deep-sea Water, and of their Analysis for dissolved Gaseous Constituents, employed on board H.M.S. 'Porcupine' during the Summers of 1869 *and* 1870. *By* William Lant Carpenter, *B.A., B.Sc., F.C.S.*

The object of the paper was to obtain a discussion on the subject, in the hope that a method might be suggested more free from error, and as readily adaptable to the exigencies of shipboard as those hitherto employed. The author was the first to adapt the late Prof. W. A. Miller's method to this purpose; and many of the results arrived at had been published in the 'Proceedings of the Royal Society' issued in 1870. The samples of water were collected by a cylinder furnished with valves opening upwards, which was fastened to the sounding-line. When used with certain precautions, it was believed that this instrument, simple as it was, left little to be desired. The method of analysis consisted essentially in boiling about 750 cub. centims. of the sea-water in a vacuum, and collecting the gas over mercury, absorbing the carbonic acid and oxygen with the usual reagents. Unless the duplicate analyses agreed closely, they were rejected. The average total quantity of dissolved gas was 2·8 vols. per 100 vols. of water. At the surface 20 to 25 per cent. of this was carbonic acid; but close to the bottom, at great depths, this percentage increased very largely, amounting to above 65 per cent. in one case.

In the more northern latitudes the proportion of oxygen was greater, and of carbonic acid less, both in surface- and bottom-water, than in the more southern.

The author then stated that there was a very generally received opinion that the water at great depths contained so great an excess of dissolved gas, that when it was brought to the surface, and the pressure thus removed, the gas escaped with

effervescence. Although he had had long experience of the collection and analysis of such water, he had not seen any thing at all to support this view. While admitting that the pressure was sufficient to retain the excess of gas in solution if it were there, the author was unable to see where was the source of the supposed excess, since there was reason to believe that every drop of water in the ocean came to the surface at one time or another; and when there, it became saturated, or nearly so, with gas at the ordinary atmospheric pressure.

In the discussion which followed, the justice of the view here put forth about the supposed excess of gases in solution at great depths was generally admitted. Several other methods of collecting samples of the water were suggested, and also apparatus for their analysis; but none of them had been tried on board ship at any distance from land.

On a proposed Method of preventing the Fermentation of Sewage.
By W. J. Cooper.

Ignition of Cotton by Saturation with Fatty Oils.
By John Galletly.

The following experiments have been made with the view of giving greater precision to our knowledge of the kindling of cotton or other exposed combustible materials which happen to have imbibed animal or vegetable fatty oils. Graham mentions* that "instances could be given of olive-oil igniting upon sawdust, of greasy rags from butter, heaped together, taking fire within a period of twenty-four hours." The danger of fire from this cause is familiar to those manufacturers who coat any textile fabric with varnishes containing drying oils, and also to turkey-red dyers, from the olive-oil employed in their process. Generally, it is stated in Watts's Dictionary that this combustion "may take place in intervals varying from a few hours to several weeks, when considerable masses of lampblack, tow, linen, paper, cotton, calico, woollen stuffs, ships' cables, woodashes, ochre, &c. are slightly soaked in oil, and packed in such a manner that the air has moderate access to them" (Watts's Dict. vol. ii. p. 880). Nevertheless there is great vagueness about the exact conditions in which actual ignition of the mass would take place, what size of a heap might be necessary, and the various powers of different oils to produce this result. Graham states, in the 'Report' already quoted, that the ignition of heaps of the materials under discussion "has been often observed to be greatly favoured by a slight warmth, such as the heat of the sun." This is a very important observation. The author's first experiments were made at a temperature of about 170° Fahr., but he had some made at a heat a little over 130°, or about the temperature a body acquires by lying perpendicular to the sun's rays; the former temperature might represent the heat attained in the neighbourhood of a steam-pipe or in front of an open fire. For completeness, the author repeated, in this paper, along with later results, some observations published a few weeks ago in the 'Oil-Trade Journal.'

Boiled Linseed-oil with Chamber kept about 170° *Fahr.*—A handful of cotton waste, after being soaked in boiled linseed-oil, and removing the excess of this by wringing, was placed among dry waste in a box 17 in. long by 7 in. square in the ends. Through a hole in the cover of this box a thermometer was passed, with its bulb resting amongst the oily cotton. Shortly after reaching the temperature of the warm chamber, the mercury began to rise rapidly, viz. from 5° to 10° every few minutes; and in 75 minutes from the time the box was placed in the chamber, the heat indicated was 350° Fahr. At this point smoke issuing from the box revealed that the cotton was now in a state of active combustion, and on removing it to the free access of air it burst into flame. In another similar experiment the temperature rose more slowly, but reached 280° Fahr. in 105 minutes, when, from the appearance of smoke, it was plain that the cotton was burning, and the whole mass was soon in a flame on being placed in a current of air. On a smaller scale a

* "Report on the Fire in the 'Amazon,'" Chem. Soc. Quart. Journ. vol. v. p. 34.

quantity of the oiled cotton that just filled a common lucifer-match box was tried; within an hour it was on fire, the temperature of the chamber being 160° Fahr.

Raw Linseed-oil, as generally supposed, does not so readily set fire to cotton as the boiled oil; but in two experiments, where the size of the box employed was $6\frac{1}{2}$ in. long by $4\frac{1}{2}$ in. square in the ends, active combustion was going on in the one case in five and the other in four hours.

Rape-oil put up as in first experiment on boiled linseed resulted, in two trials, in the box and cotton being found in ashes within ten hours. The box being put up at night, the result was only observed in the morning. In one trial the cotton did not ignite in six hours. The chamber in the cases of this oil and raw linseed was kept about 170° Fahr.; with the five following oils at a little over 130° Fahr. The quantity of waste used was loosely packed in a paper box, holding about the sixteenth of a cubic foot.

Gallipoli Olive-oil.—The two trials made with this oil gave closely similar results; in one case rapid combustion was going on in a little more than five, and in the other within six hours.

Castor-oil.—The oxidation of this oil proceeds so slowly that only on the second day the interior of the box was found to be a mass of charred cotton. Its spec. grav. (963) is remarkably high, and its chemical nature very distinct from the other vegetable oils tried, which no doubt has some intimate connexion with its slow oxidation.

Three oils of animal origin were tried with effects very distinct and instructive.

Lard-oil, an oil of an ordinary specific gravity, viz. 916, produces rapid combustion in four hours.

Sperm-oil, which has a specific gravity of only 882, and is not a glyceride, showed its unusual chemical character by refusing to char the waste.

Seal-oil, which has a strong fish-oil odour, not unlike the sperm, but a specific gravity of 928, produced rapid ignition in 100 minutes.

Comparing raw linseed with lard- and seal-oils, it would appear that the statement is not altogether correct, that drying oils are more liable to spontaneous combustion than non-drying oils. The author has also some reason to believe that the rate at which oxidation takes place does not chiefly depend on the presence of small quantities of ozotized or other easily putrefiable matters, but rather on the particular olein. However, further inquiry on this point is necessary.

The author made at least two experiments with each oil, and got remarkably uniform results. The ignition of the cotton can be calculated on for any oils with about the same certainty as the point at which sulphur or other combustible material takes fire when heated in the air; so that the term spontaneous combustion may be objected to, for the same reason that Gerhardt objects to spontaneous decomposition produced by oxidation.

The heavy oils from coal and shale being chiefly the higher olefines, have a remarkable effect in preventing this oxidation, undoubtedly by giving a certain protection from the air. Mixtures of these oils with 20 per cent. rape, gave no indication of heating whatever at 170° Fahr.; and even seal-oil, with its own bulk of mineral oil added to it, did not at 135° reach a temperature sufficient to char the cotton.

The author hopes that these remarks will lead to a more elaborate inquiry into this subject, both for scientific and practical purposes.

On the Dust thrown up by Vesuvius during the late Eruption.
By GEORGE GLADSTONE, *F.C.S.*

During the eruption which took place this spring a large quantity of fine powder which had been ejected by Vesuvius filled the atmosphere, and was deposited over the surface of the country around. Some which fell at Casa Miceiola, in the Island of Ischia, at 25 miles in a direct line from the volcano, was collected and subjected to examination. It proved to consist entirely of silica and the magnetic oxide of iron. The microscope showed that the grains were very uniform in size, and consisted of an aggregation of quartz crystals dotted over with still more

minute crystals of the iron-ore, possessing a high metallic lustre. By boiling the sand for a sufficient time in hydrochloric acid, the whole of the iron was removed, and nothing but the perfectly white quartz remained. The specific gravity of the sand was 2·68, and the grains would just pass through a wire gauze, the apertures of which measured the 16,000th part of a square inch.

On comparing this with some ironsand which occurs mixed with the soil in some parts of the country round Vesuvius, the chemical composition was found to be the same, though the grains of the older product were rather smaller, and presented under the microscope an unmistakably water-worn appearance. The specific gravity of these was 4·67 ; and they were more readily attracted by the magnet, on account of their possessing a larger proportion of iron relatively to the quartz.

Both samples differ from the magnetic ironsand of New Zealand (most probably ejected from the volcano Mount Egmont) in not containing titanium; neither do they contain by any means so large a proportion of iron oxide as compared with the siliceous nucleus.

It is probable that the sand which fell during the recent eruption of Vesuvius varies considerably in the relative proportions of iron and silica, and that as the heavier or the lighter substance prevailed would be the distance to which it would be carried by the wind from the mouth of the volcano.

On filiform Native Silver. By J. H. GLADSTONE, *Ph.D., F.R.S.*

Native silver occurs either in bunches of crystals or in threads or wires twisted in every direction, and often bent at sharp angles. The fibrous or filiform silver is tough and non-crystalline, though the threads are sometimes incrusted with crystals of the same metal. It occurs in association with a variety of minerals; for instance with quartz in Cornwall, with pyrites in Saxony, with calc-spar in Norway, and with greenstone in Chili.

Now both electrolysis and the replacement of silver in solution by a more positive metal give the silver in a crystalline condition, and the crystals often closely resemble those found in nature. But if nitrate of silver dissolved in water is allowed to act upon suboxide of copper, there shoot forth after a little time white filaments, which often run rapidly forwards into the liquid, or twist sharply round, or perhaps even double back on their course precisely like the native filiform metal. This under ordinary circumstances is only visible by means of the microscope, and most of the threads are so fine that their diameter is only about the $\frac{1}{25000}$ of an inch, and a gramme of such wire would stretch from London to Brighton. Many are very much finer than this, while others again are much thicker. They never ramify or show the usual signs of crystalline structure. Crystalline silver, however, will sometimes be deposited on these filaments, or they will terminate in thick crystalline knobs; and under certain circumstances crystalline tufts may make their appearance from the commencement. As the silver grows, the yellow or red suboxide of copper becomes black in colour. The reaction might be supposed to be

$$2(AgNO_3)+Cu_2O=2Ag+CuO+Cu\,(NO_3)_2;$$

and no doubt this decomposition occurs; but the solid residue was found to consist not merely of black oxide of copper and threads of silver, but also of an insoluble basic nitrate.

Mineral suboxide of copper was found to give the fibrous metal with silver nitrate, just as the oxide which had been artificially prepared; but attempts to prepare the metallic threads by means of the chloride of silver in saline solutions were unsuccessful.

On the mutual helpfulness of Chemical Affinity, Heat, and Electricity in producing the Decomposition of Water. By J. H. GLADSTONE, *F.R.S., and* ALFRED TRIBE, *F.C.S.*

Some metals are able of themselves to displace the hydrogen of pure water, while other metals are unable. Zinc, if perfectly pure, is just incapable of doing so; but

if it be brought into contact with another metal still further removed from the power of effecting the decomposition of water, the electric force started by the contact of the two metals enhances the chemical affinity sufficiently to make it effective; or (otherwise expressed) the joint tension upsets the state of equilibrium between the oxygen and hydrogen. The junction of the metals may be made outside the water by a wire, and the amount of action may be determined by a Thomson's galvanometer. The effect of varying the distance of two plates of zinc and copper was tried; and it was found that the chemical action increases slowly till the plates are within about an inch of one another, but on continuing to bring them nearer the action increases at a rapidly accelerating ratio. If the water be heated when it is exposed to this joint action of chemical and electrical force, it decomposes more readily. In experiments made with two plates about 1·5 inch distant from one another, the deflection of the galvanometer showed that the effect of raising the temperature from 40° C. to 80° C. was more than double of that between 20° C. and 40° C.; but in an experiment made where the copper was deposited in a spongy condition on the zinc, and the hydrogen gas produced was collected, the following numbers were obtained:—

Mean temperature.	Duration of experiment.	Hydrogen collected.	Hydrogen per hour.
°		cub. centims.	cub. centims.
2·2 C.	3 hours.	3·4	1·1
22·2 „	2 „	11·1	5·5
34·4 „	45 minutes.	10·4	13·9
55·0 „	15 „	15·5	62·0
74·4 „	10 „	29·1	174·6
93·0 „	5 „	44·0	528·0

The last column shows the extraordinary acceleration of the action due to heat.

Magnesium is capable by itself of decomposing water; but its action is greatly increased by touching it with a piece of copper, and some of the hydrogen gas then makes its appearance on the copper plate.

If instead of magnesium we take a metal less capable than zinc of decomposing water, we still find a deflection of the galvanometer if it be united with another metal still more "negative." The order for pure water seems to be:—platinum, silver, copper, iron, tin, lead, zinc, magnesium.

Experiments were made on the effect of electrical action by using the force generated in one cell of Daniell, instead of the force generated by the contact of the metals experimented on. It might be inferred that the electrolysis of water would be more easily effected between poles made of a metal that has a considerable affinity for oxygen than between poles of a metal which has little affinity. And so it is. When zinc poles were used, there was found to be more than double the action that there was when platinum poles of the same size and at the same distance were employed. The order of efficiency for poles in the electrolysis of water seems to be:—platinum, tin, silver, copper, iron, lead, zinc, magnesium. After a few minutes the power of tin was found to rise above that of copper. The other metals are in the same order as in the previous list, where they themselves produced the electricity by their joint action on water.

The effect of heat on the electrolysis of water was tried with two zinc poles. The deflection increased about fourfold between 5° C. and 80° C., and the action increases nearly *pari passu* with the temperature.

If instead of employing two poles of the same metal we use dissimilar metals, we have a current established by these two metals which, according to its direction, either adds to or subtracts from the current originating in the Daniell's cell. Thus if two poles of platinum be employed the effect with water is very minute; but if the negative pole be replaced by one of zinc, pure water is decomposed by one cell of Daniell's battery with visible evolution of hydrogen gas. The experiment was performed quantitatively with poles of silver and zinc,

Positive.	*Negative.*	*Deflection.*
Silver.	Silver.	27
Zinc.	Silver.	52
Silver.	Zinc.	7
Zinc.	Zinc.	33

When, therefore, the dissimilar metals were employed as poles, the decomposition of the water was not the mean of that producible by silver and by zinc, viz. 30, but 30 + 22 when the two forces acted in the same direction, and 30 − 23 when they acted against one another.

On a Powerful Galvanic Battery. By the Rev. H. Highton, *M.A.*

The following combination forms a cheap and simple galvanic battery, with no fumes or other inconveniences. The negative plate is carbon packed in a porous cell with precipitated sulphur, peroxide of manganese, and granulated carbon, filled up with dilute acid. Sulphuric is the best. For the positive plate, zinc is placed in a solution of caustic potash or soda.

The author stated that the potential is about 2·6 or 2·7 volts, and nearly 50 per cent. higher than a Grove battery, and that one cell will abstract magnesium from its salts. The internal resistance is rather large. If a solution of common salt be used for the positive, the potential is about 10 per cent. higher than a Grove; and with dilute sulphuric acid in the positive part of the cell it is about the same as a Grove. In the last case there is no occasion for the sulphur in the negative. The internal resistance of this last form is small; in the second form not great.

On the effect upon Meteoric Iron, as regards the capability of being forged, of previous heating to redness or whiteness in vacuo. *By* Professor J. W. Mallet, *University of Virginia.*

Three specimens were exhibited of meteoric iron from Augusta Co., Virginia. Of these, the first had been cut from the original mass by a planing-machine, and without further preparation had been forged into a tolerably perfect blade for a paper-knife. The second had been heated to strong redness in a porcelain tube rendered vacuous by a Sprengel's pump (for the purpose of examining the occluded gases), and had then been with much difficulty forged into a blade of similar kind, in which cracks and flaws were visible.

The third had been heated in like manner *in vacuo*, but to a white heat; and this specimen, it was found, could not be forged at all, crumbling under the hammer when re-heated.

The conceivable causes of this difference were briefly discussed, such as the more or less complete removal of the occluded gases, changed state of combination of the phosphorus (and sulphur), and melting out of phosphide of iron, leaving the iron porous.

On the Fusion of Metallic Arsenic. *By* Professor J. W. Mallet, *University of Virginia.*

Experiments on this subject made by Mr. Dunnington and Mr. Adger (students in the Laboratory of the University of Virginia), under the author's direction, were described.

These experiments had been undertaken in view of the generally repeated statement that arsenic cannot be fused, but passes directly from the solid into the vaporous state, and that an attempt to secure increased pressure by using a sealed tube only results in bursting the tube. The statement by Landolt * (given apparently without further details), that by using a glass tube enclosed in one of iron, the metal heated for some time to low redness under pressure may be melted into globules, was noticed only after the experiments to be mentioned had been made.

* Verhandl. d. niederrhein. Gesellschaft vom 4. August 1859, quoted in Will's Jahresbericht for 1859, p. 182.

Arsenic in the form of small fragments and coarse powder, was placed in a thick barometer-tube of soft glass and of small bore, well sealed at both ends and enclosed in a piece of wrought iron gas-tubing, closed at each end by an iron screw cap; the space between the two tubes was filled with sand, well shaken down; and the whole was heated to redness by a charcoal fire. Another, similar iron tube, placed beside the former, served to contain several little glass tubes with samples of different metals, whose fusion might afford some indication of the temperature at which that of the arsenic occurred.

Arsenic thus treated was found on cooling to have fused into a perfectly compact, crystalline mass of steel grey colour and brilliant lustre, of sp. gr. $=5{\cdot}709$ at 19° C.

It possessed a considerable degree of cohesive strength as compared with common sublimed arsenic, and even seemed to exhibit faint traces of flattening before crushing under the hammer. It gradually tarnished on exposure to the air, and presented all the chemical properties of ordinary crystalline arsenic obtained by sublimation. The temperature required for fusion lies between the melting-points of antimony and silver.

The glass tube used was found greatly distended by the tension of the vapour; and the siliceous sand—even when of the purest kind (from Fontainebleau) and previously well washed with hydrochloric acid, and then with water—was cemented together (in a way very interesting in connexion with the history of metamorphism) into a kind of artificial sandstone.

Specimens of fused and semifused arsenic, and of the tubes surrounded by a thick crust of compacted sand, were exhibited to the Section.

On the occurrence of Native Sulphuric Acid in Eastern Texas. *By* Professor J. W. Mallet, *University of Virginia.*

Not far from the Gulf of Mexico, and within twenty-five or thirty miles to the westward of the Neches river, there occur at several localities (in some instances in the woods, in others in the midst of open prairie) small drainage wells and shallow pools of water strongly sour to the taste. This sourness is due to the presence of free sulphuric acid, which is accompanied by various salts, especially aluminium and iron sulphates. At most of these points gases are continually escaping (hydrogen sulphide, marsh-gas, and carbonic anhydride), the bubbles burning readily on the application of a light.

At the bottom of the water, in some instances (as at one point where, by means of an artificial bank, a pond has been formed some 250 feet in diameter, known locally as the "Sour Lake") an earthy crust with intermingled free sulphur is observable.

A thick, tarry variety of petroleum is found oozing from the surrounding soil, occasionally to such an extent that sods taken up with a spade are set on fire, and used to give light in the open air at night. At a point in Louisiana, some fifty or sixty miles further east (where, however, the acid water does not occur, though combustible gas and petroleum are met with on the surface) a most remarkable bed of native sulphur, 100 feet in thickness, has been reached at the depth of 450 feet by boring, and a shaft is being at present sunk for its exploitation. This large mass of native sulphur is more or less mingled with calcium carbonate, and underlain by gypsum.

The circumstances connected with the occurrence together in this region of combustible gases, petroleum, sulphur, sulphuric acid and gypsum, are of great interest in relation to the mineral history of native sulphur.

The sulphuric-acid water, which seems to be probably altogether of superficial origin, is worthy of notice from the unusual strength occasionally attained. The water varies very much at the different localities and at different times. In one instance a specimen examined by Dr. Mallet contained no less than $5{\cdot}290$ grammes free sulphuric acid (H_2SO_4) to the litre, or 370 grains to the imperial gallon—this exceeding any amount hitherto reported from other localities, unless the acid spring of the Paramo de Ruiz in New Granada be an exception, examined by Lewy, who

does not state precisely how much of the very large quantity of sulphuric acid found is uncombined with bases. The water of the Rio Vinagre, flowing from the volcano of Purace in the Andes of Popayan, as described by Humboldt and Boussingault, contains only 1·11 of free sulphuric acid (SO_3?) in 1000 parts of the water, with ·91 of hydrochloric acid.

It is said, on the authority of Confederate officers having served west of the Mississippi, that during the blockade of Southern ports the galvanic batteries of telegraph offices in Texas and Western Louisiana were worked with this native sulphuric acid.

On the occurrence in recent Pine timber of Fichtelite, a Hydrocarbon hitherto only known in a fossil state. By Professor J. W. Mallet, *University of Virginia.*

Some nearly colourless crystalline crusts found in clefts between the annual rings of growth of a log of long-leafed pine (*Pinus australis*) in Alabama, were found to dissolve in boiling alcohol (more easily in ether), and on cooling to crystallize with greater distinctness in monoclinic forms.

A specimen was exhibited of this material purified by two or three recrystallizations. It had been found to agree perfectly in physical and chemical properties with the Fichtelite of Bromeis and Clark, and on analysis yielded

Carbon......	87·82
Hydrogen....	11·91
	99·73

agreeing with the formula $x\,(C_5H_8)$. The fusing-point was found = 45° C.

On Dr. Moffat's Tube Ozonometer. By T. Moffat, *M.D., F.G.S.*

The tube ozonometer is a square tube of four inches, and four feet long. It is carried upon a post about four feet high, and turns upon a pivot, so that the opening is kept constantly to the wind by means of flanges. In the middle of the upper surface there is a slit, through which a clip passes into the tube, by which is suspended a test-paper. The test-paper is changed every morning and evening. Twice daily the quantity of air which passes through the tube is ascertained by means of Biram's 4½-inch anemometer. At each observation the numbers registered by the anemometer are reduced to square feet.

On the Action of Phosphorus on Alkaline Solutions of Metals. By Dr. Oppenheim.

On the Crystallization of Salts in Colloid Solutions. By Dr. Ord.

The Crystallographic System of Leucite, hitherto supposed to be regular, is quadratic. By Herr G. vom Rath.

Any one observing the crystals of Leucite implanted in the cavities of the limestone blocks ejected by Monte Somma, the ancient crater of Vesuvius, may see certain streaks covering their faces. The phenomenon will be found continually recurring, and in fact to be characteristic of the crystals of Leucite. That they obey a regular order is seen in fig. 1. The streaks are parallel, either to the shorter edges, or to the symmetric diagonals of the trapezoidal faces. Parallelism between the streaks and the longer edges does not occur. If the streaks extend to an edge, they pass it and continue on to the neighbouring face in such a way that the streak always remains in the same plane. This plane, if we consider the form of Leucite

a regular icositetrahedron, cuts off the symmetric corners of the Leucite-form; that is to say, this plane is a face of the rhombic dodecahedron.

Examining the nature of these streaks, the author found them to be not merely superficial, but to correspond to plates of twinning. Sometimes the streaks are of a perceptible thickness, allowing the observation that their surface reflects light in a somewhat different position from that in which the face reflects it, in which the

Fig. 1.

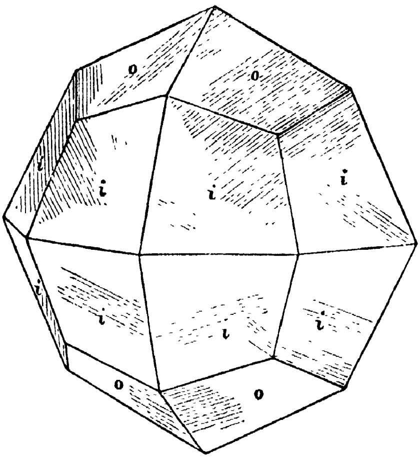
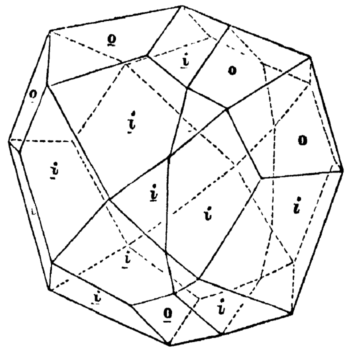


Fig. 2.



streaks are imbedded. When, for example, a face reflects light in such a manner that it is brilliant, then the streaks are dull. If now the crystal is turned round an axis parallel to these streaks about 5°, the plates of gemination become bright, whilst the face itself becomes dull. If the experiment is made where the streaks run in a diagonal direction over the faces, a smaller rotation (about $3\frac{1}{2}°$) is required.

It must be remembered, however, that in the regular system a gemination parallel to a face of the rhombic dodecahedron is not possible. Therefore it follows that the crystals of Leucite above described cannot belong to the regular system.

In order to verify this conclusion, the author examined the crystals, and found those edges which ought to be identical, supposing the system to be "regular," differing from one another to the extent of 3° 52′. The form of the Leucite is quadratic; the supposed icositetrahedron is a combination of a square octahedron o with a dioctahedron i:

$$o = (a : a : c),\ \mathrm{P},$$
$$i = (\tfrac{1}{4}a : \tfrac{1}{2}a : c),\ 4\mathrm{P}2.$$

Furthermore, the author observed the following forms of the first acute octahedron (u) $(\frac{1}{2}a : \infty a : c), 2\mathrm{P}\infty$; the first quadratic prism $(a : a : \infty c)$, $\infty \mathrm{P}$.

With regard to the twinned forms, a face of the octahedron $(\frac{1}{2}a : \infty a : c)$ is the twin-plane.

The parametric ratio of the axis of Leucite is the following:

$$a \text{ (lateral axis)} : c \text{ (vertical axis)} = 1{\cdot}8998 : 1, \text{ or } 1 : 0{\cdot}52637.$$

This ratio was derived from the measure of the lateral edge of the dioctahedron $i : i = 133° \ 58'$.

The following angles are calculated from the parametric ratio above mentioned.

	°	′
Polar edge of o ...... =	130	3
Lateral edge of o .... =	73	19
Polar edge of u ...... =	118	19
Lateral edge of u .... =	92	56

The polar edges of the dioctahedron i are 146° 9′ 28″ and 131° 23′ 16″. Calculation gives the following angles:—

$$o : i = 146^\circ\ 37'$$
$$u : o = 149\ \ 9\tfrac{1}{2}$$
$$u : i = 150\ \ 1$$

For the twin we have the angles

$$o : i \text{ or } o : i = 175^\circ\ 8\tfrac{1}{2}'$$
$$i : i = 176\ 39\tfrac{1}{2}.$$

The following measures will show how perfectly some of the crystals are developed.

Crystal 1.

$o : o'$	$=130^\circ\ 6'$	(calculated 130° 3′).
$o' : o''$	$=129\ 58$	(imperfect reflection).
$i : i$	$=133\ 58$	(calculated 133° 58′).
$i : i$	$=134\ \ 0$	another edge.
$i : i$	$=133\ 55$	" "
$i : i'$	$=131\ 24$	(calculated 131° 23¼′).
$i : i'$	$=131\ 23$	" "
$i : i''$	$=146\ \ 8$	(calculated 146° 9½′).
$i : i''$	$=146\ 12$	" "
$i : i''$	$=146\ 10$	" "

Crystal 2.

$i : i'$	$=131\ 23\tfrac{1}{2}$	
$i : i'$	$=131\ 23$	
$i : i''$	$=146\ \ 9$	
$i : i''$	$=146\ \ 6$	
$i : i''$	$=146\ 13$	
$i : i$	$=133\ 59$	
$o : i$	$=146\ 36$	(calculated 146° 37′).
$o : i$	$=146\ 37$	" "

Crystal 3.

$o : i$	$=146\ 38$	(calculated 146° 37′).
$o : i$	$=146\ 35\tfrac{1}{2}$	" "
$o : i$	$=175\ \ 8$	(calculated 175° 8½′).
$o : i$	$=175\ 11$	" "

Each measurement deals with a different edge.

These data are an exact confirmation of the deduction made from the law of twin forms. The crystallographic system of Leucite is quadratic, not regular. It might be supposed that perhaps the crystals of Leucite implanted in the cavities or geodes of the matter ejected by Vesuvius were different from the Leucites included in the lava of Vesuvius and of the neighbourhood of Rome. The author therefore made an analysis of the crystals measured above, and found the following composition:—

Silica	55·21
Alumina	23·70
Lime	0·43
Potash	19·83
Soda	1·21
	100·38

Specific gravity=2·479.

The composition of the quadratic Leucite is therefore the same as was required by the formula; and we must conclude that all Leucite, implanted or

included, is *quadratic*. The way in which the octahedron and diotahedron are balanced in Leucite is an exceptional fact in mineralogy. The streaks seen on Leucite under the microscope by polarized light are now explained; they are twin plates. And the double refraction of Leucite is explained. It is not necessary to have recourse to the lamellar polarization of Biot in order to explain the double refraction of Leucite.

On a Curve Illustrating the British Gold Coinage. *By* W. Chandler Roberts, *F.C.S.*

On the Amount of Heat required to raise Elementary Bodies from the absolute zero to their state of Fusion. *By* R. Schenk, *Ph.D.*

The scale of absolute temperature is now so much used in the mechanical theory of heat, that the absolute zero of temperature has in some degree lost its hypothetical character. Now, if we assume that a body at $-273°$ is completely deprived of heat, we can calculate the *total* heat present in it at any other temperature, provided that we know either all or several of the following data—the specific heats in its three states of aggregation and its latent heat of fusion and of vaporization, besides its melting- and its boiling-point. As it appeared to me of interest to compare the total heats possessed by different bodies in analogous conditions, I intended to calculate them first for the gaseous state, as it was likely that any relationships existing between them might then be exhibited in the most simple manner. Finding, however, that, with the exception of water, there is not a single body with regard to which all the required data are known, I was obliged to confine myself to a few elements, of which the specific heat in the solid state, the melting-point, and the latent heat of fluidity have been determined. I calculated first the total amount of heat required by these bodies to be raised from the absolute zero of temperature *just* to the point of fusion, by multiplying their specific heat in the solid state into the melting-point, as expressed in the absolute scale, and adding to the product the latent heat of fusion. The results are given in the last column but one, but do not seem to exhibit any peculiarities. That some of these numbers are almost exactly half as great as others, may be mere chance. By multiplying the numbers which

Substance.	Melting point from		Specific heat in the solid state.	Latent heat of fusion.	Total heat required to bring 1 gramme from −73° to the state of fusion.	Atomic weight	Total Heat required to bring atomic proportions expressed in grammes from −273° to the state of fusion.
	0° C.	the absolute zero.					
Zinc	433	706	0·09555	28·1	95·60 ×	65.2	= 6233·12 6·2
Cadmium	320	593	0·05669	13·6	47·2 ×	112	= 5286·4 5·2
Tin	235	508	0·05623	14·25	42·81 ×	118	= 5051·6 5·0
Lead	332	605	0·0314	5·4	24·39 ×	207	= 5048·73 5·0
Silver	1000	1273	0·05701	21·1	93·67 ×	108	= 10116·36 10·1
Bismuth	270	543	0·0306	12·6	29·2 ×	210	= 6132 6·1
Mercury	−39	234	0·03192	2·82	10·289 ×	200	= 2057·8 2·0
Iodine	107	380	0·05412	11·7	32·26 ×	127	= 4097·02 4·0
Sulphur	115	388	·20259	9·4	89 ×	32	= 2848 2·8
Phosphorus	44	317	·18870	5	64·81 ×	31	= 2009·1 2·0
Bromine	−7	266	·08432			80	
Water	0	273	·505	79	216·865 ×	18	= 3903·57 3·9
Sodium Nitrate	310·5	583·5	·27821	63	225·33 ×	85	= 19153·05 19·1
Potassium Nitrate	339·5	612·5	·23875	47·4	193·5 ×	101	= 19543·5 19·5

express the total heats possessed by equal weights (we may say by 1 gramme) of different elements by the atomic weights of the corresponding elements, I obtained the numbers tabulated in the last column, in which we at once observe a remarkable coincidence of the numbers for the elements cadmium, tin, and lead. Besides, it deserves to be noticed that the second figure is in all cases either 0, 1, 2 or 8; so that if we retained only the first figure, with the second as a decimal, the numbers obtained would not differ very much from whole numbers.

As the experimental data which I have used, although the best obtainable, leave much to be desired, and as from the recent experiments of Weber it appears that the specific heat varies with the temperature, I will not venture upon any further remarks, but confine myself to drawing attention to the fact that between the total heats possessed by different bodies in comparable conditions, there *seem* to exist numerical relationships which possibly may come out more clearly when more data are be known.

On an improved form of Filter Pump. *By* T. E. Thorpe, *F.R.S.E.*

In the St. Petersburg Correspondence of the 'Berichte der Deutschen Chemischen Gesellschaft' (No. 7, 1872), Dr. Mendelejeff described a new filter pump, constructed by Hrn. Jagno, of Moscow. It consists of a tube about 1 metre in length, and from 8–10 millimetres in diameter, to the side of which, at about 3·5 centimetres from the upper end, is affixed a side tube about 5 centimetres in length. The upper end of the vertical tube is cut slantwise, and is connected by means of a strong caoutchouc tube with a stopcock in connexion with the water-supply. In the horizontal side tube is also fixed a caoutchouc tube at least 1 centimetre in outside diameter, the walls of which must be not less than 2–3 millimetres in thickness. The end of this caoutchouc tube is pushed within the horizontal side tube, and ends in a Bunsen's valve; *i. e.* a piece of glass rod is inserted into the end, and the tube is cut by a single blow on a chisel. The edges of the slit are thus sharp, and on outward pressure being applied to the tube, they readily and completely adhere, making a perfectly air-tight conjunction. The other end of the caoutchouc tube is connected with the vessel to be exhausted. On allowing water to flow through the vertical tube, the caoutchouc tube rapidly pulsates from the opening and shutting of the valve. Energetic suction is thus set up; and it is easy by the fall of water through the 1 metre to obtain a vacuum equivalent to 700 millims. of mercury. The working of the apparatus obviously depends upon the principle of the hydraulic ram; it is readily set up at a small cost, and will doubtless take the place of the Bunsen filter pump, as it obviates the necessity of a fall of 30 feet. There are a few disadvantages connected with the use of the caoutchouc valve above described: owing to the diminution of its elasticity by long-continued working, its efficacy diminishes after a time; it not only fails to bring about rapid exhaustion, but it permits of the back-flow of the water so soon as the conjunction of its edges ceases to be perfect. To obviate these inconveniences, the author has devised an improved form of valve. At the end of the side tube is a funnel-shaped cone of metal, pierced near its apex with a number of holes; into the cone is fitted a sheet of unvulcanized caoutchouc, shaped like a filter; this presses against the sides of the cone, and effectually prevents the entrance of air or water from without. The slightest pressure from within is sufficient to disturb the adhesion of the caoutchouc and cone, and to allow of the transmission of air through the holes.

This form of valve is of a more permanent character than the other, and allows of a more rapid exhaustion. In the new form of the instrument a manometer is attached to the side tube to ascertain the degree of exhaustion; and by a screw and spring the rate of exhaustion can be regulated with the utmost nicety. Further, by means of a clamp arrangement, the vacuum within the pump can be maintained without disturbing the screw, if it should be suddenly necessary to disconnect the caoutchouc tube from the piece of apparatus to be evacuated. This form of filter pump has the great advantage of portability over the original one of Bunsen; it may be constructed in such a manner that it can be readily transported to any part of the laboratory; and it necessitates no alteration in the existing arrangements of pipes and fittings.

The Precipitation of Silver by Copper. By ALFRED TRIBE.

It has been recently shown by Dr. Gladstone and the writer that copper covered with precipitated silver removes dissolved oxygen, as cuprous oxide, from a solution of copper nitrate containing air, and also that the silver-copper couple moistened with the same liquid removes oxygen, not only from the air, but from other gaseous mixtures.

In the course of the above and other experiments, it has been necessary to completely precipitate, at various times, large quantities of silver by copper, and it has been noticed that the metal so obtained, after being thoroughly washed, always contained copper. The constant presence of this metal was considered due to dissolved oxygen in the silver solutions, or to the absorption of that gas from the air, by the produced copper nitrate, during or subsequent to the precipitation. The experiments made with the view of ascertaining the correctness of this supposition are tabulated below.

In each experiment there was employed an excess of copper, and in experiments C to I about the same volume of solution. In A and B, pieces of copper foil of the same dimensions were placed in open basins, and covered to about $\frac{1}{4}$ of an inch with ordinary silver nitrate, *i. e.* impregnated with air. In C, D, E, bottles were filled with ordinary solutions, and stoppered during the precipitation. In G, H, carbonic anhydride was bubbled through the solutions prior to the immersion of the copper, and the precipitation conducted as in C, D, E. In H, I, ordinary solutions were used.

Experiment.	Per cent. of $AgNO_3$ in solution.	Duration, in hours.	Copper in precipitated metal.	Copper per 100 parts of precipitated metal.
A	1·4	24	·0185	7·45
B	1·4	48	·0377	15·23
C	3·5	24	·0103	0·32
D	1·4	24	·0096	0·77
E	0·7	24	·0099	1·61
F	3·5	24	·0025	0·08
G	1·4	24	·0029	0·23
H	3·5	$\frac{1}{4}$	merest trace.	merest trace.
I	3·5	$\frac{1}{16}$	”	”

It appears from experiments A, B, D that the quantity of copper is increased by exposing the couple, covered with dilute copper nitrate, to the air, and decreased by precipitating in absence of air. In C, D, E the actual amounts of copper found, being nearly the same, clearly indicate that its presence is not due to oxygen in the copper employed. Moreover it is a result which would follow were the free oxygen in the respective silver solutions the cause, since it is probable that each contained about the same quantity of the gas. Experiments F and G show that the effect of saturating the solutions with carbonic anhydride prior to precipitation is to diminish the amount of copper 3–4 times, which, doubtless, is due to the partial displacement of oxygen by the more soluble gas.

In the experiments C and G there existed a trace of silver in solution after the twenty-four hours. H and I being of short duration, there was a large excess; and it is noticeable that in every case where the silver was nearly exhausted copper was found, whereas where there was an excess of silver the merest trace only existed.

It appears from the foregoing experiments that free oxygen is intimately connected with the presence of copper in silver precipitated by that metal; but whether copper exists therein as cuprous oxide, or as basic nitrate, would depend upon at what stage of the operation the oxygen plays its part. If the two actions (*i. e.* decomposition of silver nitrate by copper and of copper nitrate by oxygen) be simultaneous, basic nitrate should be found. If, however, the decomposition of the copper nitrate be not effected until the silver nitrate is so exhausted as to be incapable of action on the produced cuprous oxide, that substance should be found. One experiment made on this point, with a weak solution of silver nitrate, seemed to show that basic nitrate was not formed.

On Specimens of Agate and other Natural Colloid Silica, exhibited by G. UNWIN.

On Dinitrobrombenzene. By J. F. WALKER, *M.A., F.C.S.*

A series of experiments were made by Dr. Th. Zincke and myself, to see whether the orthomononitromonobrombenzene (melting-point 125° C.) and the metamononitromonobrombenzene (melting-point 39°), when treated with fuming nitric acid (spec. grav. 1·5) and concentrated sulphuric acid, gave the same modification of dinitromonobrombenzene, and whether one or more modifications were formed by this reaction.

We found by treating the orthonitrobrombenzene in this manner, precipitating with water and repeated recrystallization, that only the dinitromonobrombenzene, which melts at 72°, was formed. By treating the metanitrobrombenzene in the same manner, we only obtained the same modification of dinitrobrombenzene, melting at 72°.

The melting-point of each crop of crystals was taken.

The position of the replaced atoms of hydrogen are not known with certainty, whether they are 1–2 or 1–3 or 1–4. (See Kekulé, vol. ii. p. 515.)

Both these mononitrobromzenes are formed by the action of nitric acid on monobrombenzene.

If the position of the replaced atom of hydrogen in monobrombenzene be represented by the letter a,

the positions of the replaced atoms of hydrogen in orthonitrobrombenzene by a and x (x= position of (NO_2)),

and in metanitrobrombenzene by a and y (y=position of (NO_2)),

then the replaced atoms of hydrogen in the dinitromonobrombenzene (melting-point 72°) must be represented by the letters a, x, y, and it may therefore be called an ortho-meta-dinitromonobrombenzene.

On the Continuous Production of Oxygen. By J. ALFRED WANKLYN, *F.C.S.*

Tessié du Mothay has worked successfully a process by which oxygen is withdrawn from the atmosphere and subsequently liberated in a state of purity. His process consists in exposing manganate of soda to the alternate action of steam and air at a low red heat.

By the action of steam on the manganate of soda, oxygen is set free, a certain quantity of the manganate being decomposed. By the action of air the decomposed permanganate is reproduced, and is ready to be acted upon afresh by steam.

Commercially the process is a success. There is a point of great chemical interest in the process. The steam is actually taken up in the operation and forms caustic soda; and it is highly probable that the following is a true representation of the chemical changes which take place:—

$$(MnO_2)''(NaO)_2+H_2O=H_2(NaO)_2+MnO_2+O,$$
$$H_2(NaO)_2+MnO_2+O=(MNO_2)''(NaO)_2+H_2O.$$

On some New Methods of Analyzing the Ethers. By J. ALFRED WANKLYN, *F.C.S.*

It is well known that the proportion of acid derivable from an ether when it is decomposed by means of alkali, may be determined with great precision. For example, the acetic acid yielded by acetic ether may be titrated with accuracy. The author proposes to determine the proportion of alcohol obtainable when an ether is decomposed by means of alkali. The method consists in digesting a weighed quantity of the ether with excess of potash or baryta, and, when the decomposition is complete, in adding water, distilling off the dilute alcohol, and weighing the distillate, and taking its specific gravity. There is no objection to the addition of a weighed quantity of alcohol in order to facilitate the de-

composition of the ether; and of course this alcohol must be allowed for afterwards. The author had proved that alcohol may be distilled out of a strongly alkaline solution with great precision. He regarded this determination of alcohol as one of the most precise in analytical chemistry.

A second method, viz. the decomposition of ethers with hydriodic acid, was proposed. This is applicable to the fats (*i. e.* the salts of glycerine); these ought to yield iodide of isopropyl, which might be weighed, and the weight of which would afford a method of determining the proportion of glycerine in the fat.

On the Manufacture of Chlorine by means of Manganite of Magnesium.
By WALTER WELDON.

The process commences with the treatment together, in a still, of aqueous hydrochloric acid and a compound of peroxide of manganese and magnesia, which the author calls manganite of magnesium. Chlorine is evolved, and there remains in the still a mixed solution of chloride of magnesium and chloride of manganese. This mixed solution is run off into a well, from which it is pumped into an evaporating-pot, in which it is boiled down until it attains a temperature of about 300° F.; it is then run into a blind furnace, in which its evaporation is continued to dryness, after which the dry residue is gently heated with access of air. Chlorine then comes off, and there is at the same time reproduced manganite of magnesium, with which the round of operations is then recommenced.

Preliminary Note on the Preparation of Guaranine.
By JOHN WILLIAMS, *F.C.S.*

The fruit of a South-American plant named the *Paulina sorbilis* is prepared and made into rolls by the Indians of Pana. Its infusion is used as a beverage by the natives, and has an action upon the system much like that of coffee or tea. These rolls are found in commerce under the name of "Guarana:" and within a few months an infusion of this body has been strongly recommended as a cure for sick headache.

Dr. Stenhouse some years back examined this guarana, and separated its active principle, guaranine, which he considers to be identical with theine or caffeine.

Considering it a matter of some interest, the author determined to prepare some of the guaranine, and first proceeded to do so by Stenhouse's process, which he found was a troublesome one in some respects, and did not yield the body so white or pure as was desirable; and as animal charcoal refused to take up the colouring-matter, its ultimate purification became a matter of some difficulty. This led him to devise the following process, which proved very satisfactory. Guarana is reduced to very fine powder and mixed with one third its weight of hydrate of lime, and then moistened with water and allowed to stand for an hour or so, then placed in the drying-closet and thoroughly dried at a very gentle heat. This dried mixture of guarana and lime must now be thoroughly exhausted by boiling benzole, and the benzole after filtration distilled off. A small quantity of light-coloured oily matter is left, which must be treated with boiling water and placed in a basin, and heated in the water-bath until all traces of benzole have been got rid of. The liquid is then filtered through a proper filter so as to separate the oil, and the colourless aqueous portion evaporated to a small bulk; in twenty-four hours the guaranine crystallizes perfectly white and pure, and requiring no further treatment or purification of any kind.

The treatment with a little lime and solution in hot benzole is also the best mode of purifying the brownish guaranine produced by Stenhouse's process; the colour is retained by the lime, and the product is quite white. Guaranine in appearance much resembles caffeine or theine; and there can be no doubt that it is identical with those bodies. The author suspects, however, that it is rather more soluble in cold water, not crystallizing quite so quickly as pure theine, and also that it is not so bitter. He has, however, not attempted to make any comparative chemical examination of the two bodies.

The yield is, as stated by Stenhouse, large in comparison with the yield from tea or coffee; but the author has not yet ascertained the actual percentage yielded by this process.

This process has been tried with tea, and it appears to work well; but the author has not had time to finish his experiments, and cannot speak with certainty.

He has not yet tried the process upon coffee, and thinks it possible it may not succeed well upon that as upon substances containing more tannin (or astringent matter) and less oil in their constitution.

On Teaching Elementary Chemistry to Boys under 14 *years of Age.* *By* Dr. T. Wood, *F.C.S.*

This paper showed the necessity of having a compulsory elementary examination in chemistry for all pupils under fourteen years of age, before they be allowed to enter for the higher examinations requiring *practical chemistry*.

It suggested the advisability of building in all large towns a public laboratory open to any pupils for practical instruction in chemistry, because many of the present so-called teachers in chemistry, having never had practical experience in a laboratory, do not *teach* well from want of such practice.

On a Modification of Hofmann's Apparatus for Electrolysis of Water. *By* C. J. Woodward.

The extremely convenient arrangement of Dr. Hofmann for showing the composition of water by electrolysis is a very expensive one; so the author has devised a much cheaper apparatus, made thus. A shallow glass has a stoneware stopper ground into it, the stopper being perforated with three holes. Into two of these holes fit the tubes intended to receive the gases; these tubes are furnished with electrodes made from ordinary platinum foil. Into the third hole fits a tube enlarged at the top into a funnel, to receive the acid displaced as the water is decomposed.

New Derivatives from Morphine and Codeine. *By* C. R. A. Wright, *D.Sc. Lond., Lecturer on Chemistry in St. Mary's Hospital Medical School.*

During the past year further experiments have been made on the derivatives of these two alkaloids, in continuation of the researches described at the last Meeting of the Association. The principal results are as follows:—

It was shown previously that compounds are obtainable from codeine by the action of hydrobromic acid, which may be regarded as formed by a polymerizing action, the resulting products containing as their formulæ four times as much carbon as the original base—and that analogous substances are formed by the action of hydriodic acid in presence of phosphorus, hydrogen being also added on in this case. Further examination has confirmed these results in the main, with this difference, however, that the action of hydrochloric acid on codeine and morphine appears to indicate that the formulæ of these bases are double of those usually ascribed to them, while polymerides exist containing respectively twice, three times, and four times as many symbols in their formulæ as the original bases; so that the following series may be written:—

Codeine .... $=\overline{C}=C_{36}H_{42}N_2O_6$	Morphine .... $=\overline{M}=C_{34}H_{38}N_2O_6$
Dicodeine .. $=\overline{C}_2=C_{72}H_{84}N_4O_{12}$	Dimorphine .. $=\overline{M}_2=C_{68}H_{76}N_4O_{12}$
Tricodeine .. $=\overline{C}_3=C_{108}H_{126}N_6O_{18}$	Trimorphine .. $=\overline{M}_3=C_{102}H_{114}N_6O_{18}$
Tetracodeine $=\overline{C}_4=C_{144}H_{168}N_8O_{24}$	Tetramorphine $=\overline{M}_4=C_{136}H_{152}N_8O_{24}$.

Each of these bases is apparently capable of giving rise to a large number of derivatives, the substances described last year being mainly derivatives of tetracodeine and tetramorphine; it has been found that the formulæ there attributed are only one half the true ones. In the codeine series all these polymerides and several derivatives from each have been obtained. In the morphine series the polymerides

themselves have not yet been isolated, nor have trimorphine derivatives been obtained as yet with certainty; but tetramorphine and probably dimorphine derivatives have been obtained: some of these are formed by the removal of the elements of water from the polymerides themselves, thus constituting "apo-" or anhydro-bodies. It appears probable that apomorphine, the earliest known derivative (obtained some years ago by the late Dr. A. Matthiessen and the author), is really a derivative of dimorphine.

When hydriodic acid and phosphorus act on codeine, hydrogen is added on, methyl is eliminated as iodide, and polymerization is brought about, one or other of a series of substances being obtained, all denoted by the general formula

$$(\bar{M}_4+H_{16})-nHI \pm pH_2O;$$

by prolonging the action, substances are obtainable of the general formula

$$(\bar{M}_4+H_{16}-O_8)+nHI \pm pH_2O.$$

When morphine is subjected to the same treatment, products are found which are apparently absolutely identical with the corresponding codeine products; much fewer derivatives, however, are obtainable from morphine, the fact of there being no methyl to eliminate and thus place the substance in a quasi-nascent condition, being probably the reason for this difference: thus all the morphine derivatives hitherto obtained by these means belong to the first of the above two series.

Although most of the substances hitherto examined have energetic physiological actions, all these derivatives, whether from codeine or morphine, are, comparatively speaking, inert, doses up to eight grains (0·5 grm.) being given to an adult she terrier without producing any symptom more marked than a peculiar kind of diarrhœa, lasting for a few hours.

These results, together with those formerly obtained, indicate that codeine is a kind of methylic ether of morphine, their relative formulæ being

$$\left.\begin{matrix} C_{34}H_{36}N_2O_4 \\ (CH_3)_2 \end{matrix}\right\} O_2, \qquad \left.\begin{matrix} C_{34}H_{36}N_2O_4 \\ H_2 \end{matrix}\right\} O_2.$$

It is noteworthy that both from codeine and from morphine the same compound, $(\bar{M}_4+H_{16})+9HI-4H_2O$, is derivable. The formula of this substance,

$$C_{136}H_{161}IN_8O_{20}, 8HI,$$

is incapable of being halved, and indicates that these iodized bases are really C_{136} compounds, and not C_{68} bodies as at first supposed. On account of the similarity in properties between these iodized derivatives and the chlorotetracodeine, bromotetramorphine, &c. obtained by the action of hydrobromic acid on codeine, the formulæ of these latter are also considered to be double of those formerly attributed to them; *i. e.* they are viewed as $C_{144}-C_{136}$ compounds, and not $C_{72}-C_{68}$ bodies. Inasmuch, however, as they still contain four times as much carbon as the original codeine and morphine (these bases being doubled in formula, as above mentioned), the old names are still applicable; and this class of bodies, which are specially distinguished by being amorphous and insoluble in ether, may be conveniently alluded to as the "*tetra-bases*."

To obtain the polymerides of codeine themselves without further alteration by secondary reactions, the action of acids other than hydracids was examined. Phosphoric acid at 200° (the aqueous solution of codeine in excess of glacial acid being gently boiled down) yields *dicodeine*, soluble in ether, amorphous, but forming crystalline salts—and *tetracodeine*, much resembling in properties all the other "tetra-bases" examined, being insoluble in ether and amorphous, and forming amorphous salts. These two bases appear to be identical respectively with the "isomer of codeine" of Armstrong and the "amorphous codeine" of Anderson, both prepared by the action of sulphuric acid on codeine. On examining this reaction a third polymeride was also found to be formed: this is amorphous and soluble in ether, but forms amorphous salts; on account of its being in many respects intermediate between dicodeine and tetracodeine, it is considered to be *tricodeine*. This base is *not* produced by the action of sulphuric acid on dicodeine; this action, however, gives rise to tetracodeine in quantity.

The proof of the correctness of the formulæ attributed to dicodeine and tetra-

codeine is as follows. When dicodeine is treated with hydrochloric acid, it undergoes the following reaction,

$$C_{72}H_{84}N_4O_{12}, 4HCl+HCl=H_2O+C_{72}H_{83}ClN_4O_{11}, 4HCl.$$

The resulting chlorinated base is soluble in ether, and gives amorphous salts: hence it cannot be a tetra-base; and hence it follows that dicodeine has a C_{72} formula. When dicodeine itself is similarly treated, the first product formed appears to contain chlorine and carbon in the ratio of 1 to 36; whence codeine itself is a C_{36} body. Tetracodeine evidently belongs to the series designated as the "tetra" series; and these have been shown to be C_{144} substances. Hence tetracodeine has double the formula of dicodeine, which is double that of codeine; whence the names.

The action of hydrochloric acid on tri- and tetracodeine, however, is quite different: in the case of tricodeine, the elements of water are removed, and an "apo" base containing no chlorine at all is formed; tetracodeine, on the other hand, undergoes no change whatever when heated for a long time with hydrochloric acid.

The action of hydriodic acid and phosphorus on codeine, dicodeine, and tetracodeine is again very different, as exemplified in the following reactions:—

Codeine...... $4\overline{C}+36HI=8CH_3I+4H_2O+I_{16}+\{(\overline{M}_4+H_{16})+12HI-4H_2O\}$

Dicodeine.... $2\overline{C}_2+25HI=8CH_3I+4H_2O+I_8+\{(\overline{M}_4+H_8)+9HI-4H_2O\}$

Tetracodeine.. $\overline{C}_4+18HI=8CH_3I+2H_2O+\{\overline{M}_4+10HI-2H_2O\}$

With the codeine H_{16} is added on to $\overline{M}_4$; with the dicodeine, H_8 only; and with the tetracodeine, no H at all: a tetra-base results in each case. The product from dicodeine has the formula $C_{136}H_{153}IN_8O_{20}, 8HI$, which cannot be halved; the production of this substance (which is the end product of the reaction) shows again that the tetra-bases do not contain less than C_{136}.

When morphine is treated with phosphoric acid at 200°, two products are obtained corresponding in properties to dicodeine and tetracodeine; these are not, however, the morphine polymerides, but are "apo" derivatives therefrom. One is soluble in ether, and forms crystalline salts though amorphous itself; this is produced only in small quantity, and appears to be identical with apomorphine, which is accordingly viewed as a dimorphine derivative—

$$2\overline{M}=4H_2O+(\overline{M}_2-4H_2O)=4H_2O+C_{68}H_{68}N_4O_8.$$

The other is a tetra-base formed by the reaction

$$4\overline{M}=2H_2O+(\overline{M}_4-2H_2O)=2H_2O+C_{136}H_{148}N_8O_{22}.$$

This latter gives rise to new derivatives when treated with hydrochloric acid or hydriodic acid; it is quite as powerful an emetic as morphine, according to Dr. Stocker's experiments, but does not seem to produce so much after-prostration.

Most of the above products have not yet received names, on account of their complicated composition; the term *diapotetramorphine* has been given to the last-described base on account of its having the composition of tetramorphine minus two proportions of water, $=\overline{M}_4-2H_2O$. Applying the same kind of nomenclature to apomorphine, this base should be termed *tetrapodimorphine*, having the composition of dimorphine minus four proportions of water, $=\overline{M}_2-4H_2O$.

A large number of other products have also been obtained, and are now in course of examination. It is hoped to extend the investigation of the opium alkaloids to some of the less-known ones, such as narceine and papaverine. In reference to this point the author cannot conclude without acknowledging the extreme kindness and liberality of Messrs. Macfarlane of Edinburgh; during the course of these researches these gentlemen have furnished gratuitously large quantities of several alkaloids, including the rarer ones, and amounting in the aggregate to several pounds weight of materials of the highest degree of purity. Without the help thus liberally bestowed, the investigations would have been impossible.

GEOLOGY.

Address by ROBERT A. C. GODWIN-AUSTEN, *F.R.S., F.G.S., &c., President of the Section.*

THE Geological Section is fortunate in respect of this year's place of meeting of the British Association. The county of Sussex presents a wide range to the geological observer: there is the great freshwater Wealden series, next the entire Cretaceous group, then portions of the Nummulitic group, including the unique fossiliferous beds of Bracklesham; at Selsey is to be seen a remnant of a definite Tertiary period, of which at no other place in England is there any record; lastly, the evidence as to local conditions during the Glacial period is peculiarly interesting. This rich field has not wanted competent labourers, foremost amongst whom must be named Dr. Gideon Mantell, who in his day did so much by his zeal and knowledge to diffuse a taste for his favourite pursuit. There must also be added the names of Mr. Martin, of Pulborough, and Mr. Dixon, of Bognor.

It might perhaps be a fitting preliminary to the local communications which we may expect in the course of this Meeting, should I here give a summary of what has been already done with reference to the geology of this South-east of England; but to many who meet now in this Section, very much of such a survey would be familiar. Instead of this I propose to call attention to what is the peculiar feature of our local geology—namely, its great Wealden formation, the product of that vast lake or sound which, at a time before a particle of the chalk hills of Sussex had been formed, covered an area larger than the whole of the South-east of this island. What I shall endeavour to put before you, a point not generally understood, is with reference to the place of formations akin to our Wealden in the records of past time, to enable you to realize what were then the geographical conditions of the northern hemisphere, what the distribution and extent of other areas of fresh water, the equivalents of our Wealden.

Place of the Fresh- and Brackish-water Formations on the Geological Scale.

When a general view is taken of the successive physiographical conditions of bygone geological periods, it is seen in respect of each, such as those of the Palæozoic period or of the Mesozoic, of the Jurassic, Cretaceous, and Nummulitic, which all represent distinct periods of past time and are all the products of purely marine conditions, that what is at present terrestrial surface was at those times to a great extent covered by water, and that the great geological formations are merely old sea-beds.

When on a projection of the northern hemisphere the known extent of each of these old seas is represented, as on the maps exhibited, it is also seen to how great an extent, at those times, the area of water exceeded what it is at present; at each of these great periods the northern hemisphere must have presented just such a preponderance of water as the southern hemisphere does at present: and it is further to be remarked how closely the area of one period of northern geological submergence corresponds with the others, as the Nummulitic with the Cretaceous, and the Cretaceous with the Jurassic. Whatever the cause, there is to be seen in this a recurrence of like conditions at enormously long intervals of time.

If next the internal evidence to be derived from these Mesozoic formations be taken, it is to be seen, as is familiar to most geologists, that each, when most complete, presents a like order of change from its older to its newer portions.

Over the mid-European area, shallow-water accumulations, such as shingle and sand zones (infra-Liassic), preceded the deeper-water shales and limestones of the Lias. Jurassic Oolites follow upon these, indicating somewhat decreased depths for the Middle Jurassic series. Oscillations of surface mark this period; and with respect to its physiography, Mr. Darwin has given his opinion that the Malay archipelago, with its numerous large islands separated by wide and shallow seas, probably represents the former state of Europe, when the Middle Jurassic beds were accumulating. Next follow deep-water depositions, when the widely spread Kimmeridge series was formed, ending upwards with the Portland beds.

The Cretaceous group, as it is exhibited here in the south of England, where its vertical thickness is very great, presents in its lower beds (Neocomian) a marine fauna which indicated to Edward Forbes a limited sea, with depths not exceeding 18 fathoms. Sand-zones hundreds of feet in thickness overlie these. The argillaceous Gault, in its composition and fauna, is a deep-water deposit, followed by shallower-water sands (Upper Green Sand) indicating oscillating conditions as to depth of water, to which succeeds the widely spread oceanic deposition of the white Chalk. Here recurring conditions come about in like order as in the Jurassic series; and a corresponding illustration might be derived from the physical changes indicated in the course of the Nummulitic period.

With respect to none of these marine geological formations is there any indication whatever that one passed into, or was in continuous sequence with, another, either stratigraphically or geologically; on the contrary, wherever there is apparent continuity, either upwards or downwards, it is by change or transition from one set of conditions to another wholly different. The purely marine Upper Silurian beds of the Welsh border are followed conformably by the Old Red Sandstone, which last is now universally accepted as a lacustrine formation, the place of which, in time, was intermediate between the middle Palæozoic group and the upper or Carboniferous, which commenced with the so-called "Devonian." The positions and extent of the "Old Red" lacustrine beds in all parts of the British Islands indicate, even at this day, to what extent Silurian sea-bed had become terrestrial surface, to which the lacustrine basins were subordinate.

In the contrary direction, and in our own area, the next group, indicating widely spread marine conditions, that represented by the Devonian and Mountain-Limestone formations, sets in (as in North Devon) with shallow-water sands and a marine fauna (Lower Devonian), in sequence to "Old Red" depositions with fresh-water fishes and crustaceans. There is no continuity from "Old Red" into the earliest Devonian beds, any more than from uppermost Silurian into Lower "Old Red." (Phillips's Geology of Oxford, pp. 77–79.)

The later Palæozoic ocean-floor, now our Mountain Limestone, in turn became terrestrial surface, on which the Coal-measures were accumulated, and over which the abundant vegetation of that period established itself. The Coal-measures represent so much of the surface of their time as, from position, favoured expanses of fresh and brackish waters, and alternations from one set of conditions to the other.

Geologists are familiar with the amount of physical change which took place over the European area after the coal-growth period. The subsequent condition of surface which resulted is still distinctly traceable. The Permian-Trias period presents true Aralo-Caspian conditions, physically defined, subordinate to the same continental area.

The marine Jurassic series, next in sequence, was succeeded by that period of terrestrial conditions to the more detailed physiography of which I here propose to call your attention. It may suffice on this occasion to state that at the end of the great Cretaceous period the area of those seas, in our hemisphere, down to depths at which the great chalk floor had been deposited, became part of a continental land, on which the freshwater formations of the times which preceded the marine Nummulitic were accumulated.

These evidences of successive physical conditions over the northern hemisphere indicate an order of recurrence of corresponding conditions, and, as already noticed, of a progress of change which, in the course of each period, came about in a corresponding order. Great periods, during which wide marine conditions prevailed, alternated with others of wide terrestrial surfaces. The marine periods, as we measure them by the products of the agents which seas and oceans call into action, must have been of vast duration. In like manner we may feel assured that the great freshwater formations are not, as some geologists have supposed them, mere subordinate parts of the great marine groups, as our "Wealden" of the "Cretaceous," but rather true intermediate groups, of equal geological value with them in the estimate of past time.

The Wealden Formation.

Mr. Martin proposed this designation for the assemblage of freshwater depositions exhibited in the counties of Kent, Surrey, and Sussex, and which may be

described generally as consisting of thick accumulations of sands and sandstones for a lower or earlier part, surmounted by a great argillaceous deposit (Weald Clay). Mr. Webster suggested the propriety of uniting the Purbeck beds, Hastings sands, and Weald Clay into one group, the whole being mainly a consecutive freshwater series. It must be understood, however, that there is not a definite line separating the Hastings sands from the Weald Clay: all that is signified is, that sands predominate for the lower, and clays for the upper portion of the Wealden depositions; but just as thick bands of clay occur in the lower series, so bands of sandstone occur in the upper.

The arrangement adopted by the Geological Survey, in descending order, is:—Weald Clay, Tunbridge-Wells Sands, Wadhurst Clay, Ashdown Sands, Ashburnham beds (which, in Sussex, are the equivalent of the Purbeck beds of Dorsetshire).

The lower sands are well seen on the coast at Hastings, whence they took their name, and extend thence continuously to near Horsham, rising into the central ridge of the Wealden elevations of St.-Leonards, Tilgate, and Ashdown forests. On every side this tract is bounded by the Weald Clay, which extends to the base of the escarpment of the Lower Green Sand, beneath which it passes.

This surface of freshwater strata, so defined, extends for seventy miles from E. to W., and has a breadth from N. to S. of thirty-five miles. Over the whole of this area the freshwater depositions attain a great thickness; the lower sandy group may be taken as 800 feet, and the Weald Clay as 450 feet at least.

To realize the conditions under which these accumulations were formed, the now upraised central sandstone ranges must be put back to their original horizontal position, and the whole series must be regarded as the infilling by freshwater rivers of what was an area of depression with reference to the terrestrial surface of the time. This Wealden formation can be traced far beyond the limits of the denudation of the S.E. counties. In a southerly direction it occurs in the Isle of Wight, with its two divisions of Weald Clay and Lower Sands. In this quarter the Weald Clay is reduced to a thickness of 68 feet. In a westerly direction (Swanage Bay) the Wealden sands have a great thickness, and are surmounted by only a thinnish band of Weald Clay or deep-water deposit; and both divisions decrease rapidly in the extension of the formation across the Isle of Purbeck, and have not been recognized in the Isle of Portland, from which, if they even extended there, they must have been denuded off.

In a northerly direction, several sections about Oxford, as from Shotover Hill to Great Hazeley, from Wheatley to Tetsworth, from Brill through Long Crenden to Thame, from Whitchurch to Aylesbury, extending from S.W. to N.E. for a breadth of thirty miles, show Purbeck beds and freshwater ferruginous sands passing beneath Cretaceous beds. It is obvious that the Wealden formation has been cut back in this quarter, and that originally it had a much greater extension. In this quarter, too, the ferruginous sands overlap the Purbeck beds, showing that the lake had here widened its area beyond the dimensions of the Purbeck lake.

From Oxford* to the Vale of Wardour is an interval of seventy miles, from over which the Portland Oolite has been removed, except at Swindon, at which place there are beds which are unmistakably referable to the Purbeck group; and it is a fair inference that it is to this denudation that is to be attributed the absence of the lacustrine depositions which everywhere on our area, and on much of that of continental Europe which was adjacent, follow next upon the Portland stage. Such being the case, the smallest possible dimensions which can be assigned to the great Wealden lake, are that it extended from beyond Aylesbury to Portland for 120 miles, and from Portland to to the Boulonnais for 200 miles.

From Rye to Portland the Wealden beds pass out of sight beneath the level of the English Channel. The valley of the Channel is the result of the disturbance which produced the E. and W. lines of the South of England, and was produced subsequently to the Nummulitic period.

Dr. Fitton remarks that, the subdivisions of the Wealden formation, especially at its upper part, being in some measure arbitrary, it is difficult to determine to

* *Vide* evidence as to range of Wealden deposits, Phillips's 'Geology of Oxford.'

which of the three groups any outlying depositions ought to be referred. (Geol. Trans. vi. p. 323.)

Such a difficulty existed when corresponding portions of a formation were supposed to require an agreement in mineral character and composition; but it happened at all times, as now, with respect to the depositions within areas of water, whether of lakes or seas, that the beds which were strictly equivalent in respect of time, varied, from place to place, from marginal shingle to submarginal sand-zones, and deeper and more distant argillaceous or calcareous mud-beds. Considered in this way, the distant Oxford and Buckingham portions of the Wealden formation are referable to the submarginal accumulations of the great lake, and may be synchronous with "Wealden clays." For the threefold division of the Wealden series into Purbeck beds, Hastings sands, and Weald clay, must therefore be substituted the more natural divisions of Lower Wealden for the Purbeck series, and Upper Wealden for the series as exhibited in the S.E. of England, which may be of sand and sandstone or Weald clay according to local conditions of depth.

There are indications that changes in the area surrounding the Wealden formation took place in the progress of that series. The lower and earlier sandy deposits indicate only inconsiderable depths of water. Yet the vertical thickness of the series may be estimated at nearly 2000 feet: for that area, at least, progressive depression must have been going on, but not uninterruptedly. As regards the upper and lower divisions of the formation, the difference consists in the greater coarseness of the detritus of the upper, and in the evidence of strong currents setting in definite directions, in an extension of the area and of an increased depth—so that at the later stage a central area of deep-water depositions may be defined, as well as the directions in which such conditions thinned away. Great changes took place in the depth of the water of the lake, as indicated by the alternations of the drift-sand beds with deeper-water mud deposits, and in places by the conversion of lake-bed into land-surface, upon which plant-growths established themselves for considerable periods of time, and which were again submerged.

Such changes as these seem to imply change in the physical geography of the land region to which this great freshwater area was subordinate—such, for instance, as would give rise to larger rivers, greater influx of fresh waters, and stronger currents.

The successive conditions indicated by the great Wealden group as a whole are, for the first stage, that of an extensive shallow lake, or sound, at the sea-level of the time, the inflowing waters to which were largely charged with lime derived from the surface of Portland Oolite, from which they came. This is the Purbeck stage, which commenced with a long period of purely freshwater conditions. Brackish-water conditions followed, with a change of fauna. Mollusca such as *Corbula*, *Cardium*, *Modiola*, *Rissoa* appear, presenting, as was observed by the late Edward Forbes, the change of character which the Caspian-sea mollusks have at present in adapting themselves to brackish water.

During the Middle Purbeck series the alternations from fresh- to brackish-water conditions were frequent and apparently of short duration, till finally it was closed as it commenced by a thick set of purely freshwater depositions.

The changes in the Purbeck series are readily accounted for by reference to areas of water such as occur on the American coast at present, and which may be salt or brackish, according to the extent to which the sea-waters are excluded by sand-bars from mixing with the fresh waters flowing from the land.

The S. and E. coast-line of our Wealden lake must be looked for beyond the area of our island.

Wealden Formations of the European Surface.

The elliptical form of the Wealden elevation and denudation has its completion on the east in Picardy, across the English Channel. In the Boulonnais there occur ferruginous sands like those of Shotover, full of freshwater shells (*Unio*), overlying Purbeck limestone, and passing beneath the Cretaceous formation, just as happens in this country. These Wealden beds are not now of any considerable thickness, having been reduced by the denudation of the district. They are so mixed up with pebble-beds in places as clearly to indicate a marginal line, which

may safely be placed to the north of the Boulonnais denudation; for the Wealden depositions proper hardly rise to the level of the Palæozoic rocks of Marquise. The great fissures and pot-holes in the limestones there, which have been produced under subaerial conditions, and filled with sand, mould, and much vegetable matter, had been produced antecedently to the deposition of the Gault over that area.

The Wealden beds of the Boulonnais were formed beneath the waters of the same lake as our own. This freshwater area had an extension southwards; thus M. d'Archiac refers the mottled clays beneath the iron-sands and sandstones at Havre to the Wealden series of this country; so that the limits of our lake in that direction, or in the south, lay somewhere along the line of the English Channel.

Sixty miles to the south of the Boulonnais is a district known as the Pays de Bray, which is an elliptical valley of elevation and denudation, like our own Wealden on a small scale, extending from Beauvais to Neufchatel, a distance of forty-five miles. In this denudation the lowest beds exposed belong to the marine Jurassic series (Portland Kimmeridge). Next above the Portland stone is a Wealden formation. "Les dépôts regardés comme fluviatiles sont les plus voisins de l'étage Portlandien, et forment le groupe inférieur du terrain Néocomien" (Graves, Oise, p. 55). The remains of the fishes, *Cyrenæ, Cyprides,* and ferns are such as occur in our Wealden.

The thickness of this freshwater formation is inconsiderable compared with our Wealden. The separation of the freshwater formation from the marine Portland is well defined; not so that betwixt the Wealden and Neocomian: here, as in the Punfield section, the freshwater and marine conditions seem to have alternated; and the manner in which this takes place suggests the supposition that the influx of a considerable body of fresh water from the land of the time took place not far from this place.

Neufchatel is seventy miles south of Boulogne; the Wealden beds, as we have seen, indicate that the series extended southwards from Marquise; and it is no unreasonable supposition that the deposits of the Pays de Bray were formed under the waters of the same lake as were those of our own Wealden.

Such, then, were the dimensions of the Wealden lake, or sound. It extended from parts of Buckingham, on the north, half across the English Channel on the south, a breadth of 160 miles; in the contrary direction it reached from Wiltshire far into France, beyond Beauvais for 250 miles.

In another part of France, Départ. de l'Aube, M. Cornuel has described a fluvio-lacustrine formation between the Jurassic and Cretaceous formations at Vassy, containing *Iguanodon,* several species of *Unio,* and *Planorbis.* The lacustrine formation at Cimey is in a corresponding geological position.

In the Jura, Villers, Forcine-le-bas, the Portland beds are followed by hard bluish marls, calcareous marls, and gypsum, the whole very like our Purbeck series. These lacustrine formations are interesting, as they seem to show the existence of a chain of lakes stretching across France into Switzerland for 260 miles, with a general direction parallel to the axis of Artois, and thus connected as part of one great lake-system with our Wealden.

In France, Dép. des Deux Charentes, some 350 miles due south of our Sussex coast, there occurs a great freshwater formation in intermediate position between the Portland Oolite and what were then the lowest beds of the Cretaceous series. Like our own Wealden, this also is exhibited over a surface from which the Cretaceous strata have been denuded. This formation has engaged the attention of many French geologists, more particularly of M. Coquand, who has determined its age and purely lacustrine character, and who puts it as the equivalent of the Purbeck beds of England; in this he seems to be guided by the general likeness as to composition and the presence of *Physa Bristowi,* a well-known Purbeck species.

The sequence of events at this place was as follows:—Subsequently to the formation of the Portland Oolite the sea-bed became terrestrial surface; and subsequently again to that a depression, extending from Chateauneuf, near Angoulême, to beyond the Island of Oléron, became the site of a great freshwater lake. From St. Jean d'Angely to Chateauneuf is a distance of thirty-five miles; and from Chateauneuf to Oléron, S.E. to N.W., is upwards of 100 miles; but then figures do not give the full dimensions of this freshwater area, as its deposits have

been reduced by denudation on the north and pass beneath the Cretaceous series on the south. The original lake must have had a westerly extension seawards; and its area must have equalled that of Lake Ladoga.

The feeders of this lake are more easily accounted for than in the case of our own Wealden. Such a lake would necessarily have received all the streams descending from the western slopes of a terrestrial surface of very ancient date, namely the granitic district of Central France.

In North Germany there is a well-exhibited Wealden formation, extending from Bentheim by Rheine, with a breadth from N. to S. of twelve miles. From Ibbenhüsen it reaches on the S. side of the Triassic and Palæozoic axis of Osnaburg for many miles. It is everywhere in an intermediate position betwixt the Upper Jurassic and Lower Cretaceous formations. On the N. of the axis it spreads for seventy miles to Minden, certainly as far N. as the Steinhuder Meer near Hanover, and as far S. as the Hils district. From W. to E. the ascertained extent of this lake is upwards of 120 miles.

At Bentheim the dark Wealden clays, with bands of limestone and spathic iron-ore, with *Cyrenæ*, *Melaniæ*, &c. like those of Sussex here, are 400 metres thick; so that the real dimensions of this northern lake were very much greater than those here given.

These large lacustrine areas imply that there was at that time a corresponding extent of terrestrial surface. And it may fairly be asked, what is the geological evidence of such a condition? There occur over parts of Belgium the remains of such a terrestrial condition of surface beneath the lower Cretaceous beds there (Tourtia), consisting of variegated sands and clays, with much diffused vegetable matter, and occasionally with beds of lignite; such surfaces can be traced along the line of the Belgian coal-field (Mons), and overlying parts of the Palæozoic series. These beds are not of sufficient dimensions to be termed lacustrine, but have all the characters of the deposits of ponds and marshes; and M. Dumont has properly referred them to the Wealden period. Suchlike evidence of terrestrial conditions recur over a wide European area; such are the subcretaceous beds of pisiform iron-ore, of subaerial origin, and the wide area over which freshwater sands with *Pterophyllum*, *Pecopteris*, *Cycadites*, &c. of our Wealden are found.

The break betwixt the marine Jurassic and Cretaceous formations is very distinct, physically and zoologically; and it may be fairly asked, in what way do the forms entombed in the products of the intercalated period of terrestrial-surface conditions serve to throw any light on what took place during that long interval of time?

That the earliest Purbeck-Wealden fauna should have Jurassic relations—that is to say, that it must have synchronized with such wherever that formation was being continued, is only what might be expected; for the whole of the bed of the Jurassic seas in the northern hemisphere was not converted into subaerial surface at once. Midway in the course of the Purbeck-Wealden series there is evidence of the recurrence of marine conditions, with Portlandian forms, such as *Ostrea distorta* and *Hemicidaris purbeckensis*. It was on this ground that Prof. E. Forbes suggested the propriety of placing the Purbeck series with the Jurassic in systematic grouping; for it showed that up to the time of the Middle Purbeck beds the marine fauna of the nearest seas was still Jurassic.

The considerable extent of land surface in the northern hemisphere during the whole of the marine Jurassic period, and the local conversion of any portions of such sea-bed into land, whether in the course of the deposition of the Lower Jurassic series (Stonesfield), or between the lower and middle (Brora, Staffin), or at the uppermost stage (Portland), would be merely the addition of so much more to the existing land.

The forms of life which would colonize such new surfaces would be such as migrated from the older adjacent lands; if any change took place in the fauna or flora of such old land-surface in the course of the production of the marine Jurassic series, it would be recorded in the forms entombed in the lacustrine formations of the several stages here alluded to.

The fossil plants and freshwater shells from Brora, Loch Staffin, and the Wealden seemed at first to certain well-known and competent naturalists to show

that an identical set of forms ranged throughout. A minutely critical examination has since indicated shades of difference; yet it may be questioned whether such are greater than different localities in the same zoological province now present, allowance being made for differences in the conditions of these old estuarine and lacustrine areas.

The relations of the land-surface forms of the Wealden formations of the European area have been recognized by all naturalists as being Jurassic rather than Cretaceous. In this the Purbeck-Wealden group offers an exact counterpart, zoologically and geologically, of the Permian-Trias group; just as the marine zoological relations of the Permian are Palæozoic, so those of the Purbeck are Jurassic; and when next after each of these, and after the wide spread of purely marine conditions over the northern hemisphere at each period, the marine fauna is seen to have undergone a complete change, in the one case Palæozoic forms go out, and for ever, to be succeeded by Mesozoic or Jurassic; in the other Jurassic forms go out and the Lower Cretaceous come in, and are those which interchange with the uppermost Wealden fauna at Punfield and the Pays de Bray.

Did time allow, I might call attention to the results of the labours of the distinguished palæontologists who have described the forms of life of the Wealden period, both of animals and plants. From them we know that Crocodiles and Chelonians, referable to many genera, abounded in the Wealden waters. These, with the Cycadeæ of the land, sufficiently mark the temperature of that time as being much higher than it is here at present. With respect to the numerous large terrestrial Dinosaurs, it is observable that as yet they are nearly all peculiar to our Wealden lake. The relative level of this lake seems throughout to have been such as to have admitted of easy communication and interchange with the waters of the sea; and this condition may serve to account for some of the peculiarities which its fauna presents.

On the Temperature and other Physical Conditions of Inland Seas, in their relation to Geological Inquiry. By William B. Carpenter, *M.D., LL.D., F.R.S.*

After giving a brief account of the Temperature-phenomena of the Deep Sea, as made known by recent observations (see Proceedings of Section A, p. 48), Dr. Carpenter contrasted these with the Temperature-phenomena of the Mediterranean and other inland seas. In the Western basin of the Mediterranean, the temperature of the *surface* varies with the season, from about 54° F. in winter to 76° or even 80° in summer. But the superheating influence of solar radiation does not extend much below 50 fathoms, and ceases to manifest itself at 100 fathoms; and from this depth to the bottom, which in some parts lies at a depth of 1600 fathoms, there is a *uniform temperature* of 54°. From the coincidence of this uniform temperature with that which seems to be the constant mean of the earth's crust in the Mediterranean area,—as indicated by that of the deep tanks in Malta, and of a cave in Pantellaria,—the Author had thought, in the first instance, that it might be dependent upon *sub*jacent warmth. But subsequent inquiries have satisfied him that it is mainly determined by the average *winter*-temperature of the area. As he pointed out last year (Proceedings, p. 51), the marked contrast between the temperature of the deep stratum of the Mediterranean and that of the outside Atlantic, obviously shows that depth *per se* has no effect in reducing Oceanic temperature, and that the coldness of the Sea-bottom in the Atlantic must depend on a flow of glacial water from the Polar area. Hence it may be concluded that if the Strait of Gibraltar were deep enough to admit the cold stratum, the temperature of the deeper portion of the Mediterranean would be considerably lower than it is. But as the "ridge" between Capes Trafalgar and Spartel is shallow enough to prevent the entrance of any but the surface-stratum of Atlantic water, the winter-temperature of which is as high as that of the Mediterranean, the latter cannot be chilled by it; and the constant temperature of the whole mass of its water from 100 fathoms downwards may be regarded as its *isocheimal*,—the solar heat to which its surface

is subjected in summer expending itself in producing evaporation, and not reaching the depths beneath.

In the Eastern basin of the Mediterranean, the axis of which is about 2° further south than that of the Western, the constant temperature, as determined by two very deep soundings (one of them extending to more than 1900 fathoms) is 56°, which seems to represent its *isocheimal*,—this basin being cut off from the intrusion of any colder water, except the comparatively small quantity that may come down into it from the Euxine.

Now one marked consequence of this uniformity of Temperature in the deep Mediterranean basins, from 100 fathoms downwards, will be an absence of that Vertical Circulation, which, in the Oceanic areas, brings every drop of water at some time or other into contact with the Atmosphere, and thus effects its aëration, —the excess of Carbonic Acid which it has derived from Animal Respiration, and from the Decomposition of Organic matter, being removed, and replaced by Oxygen. Hence, if the whole of the deeper water of the Mediterranean is in a state of stagnation, it might be expected to become highly charged with Carbonic Acid (its Oxygen being proportionately reduced), through the decomposition of the large quantity of Organic matter brought down by the great rivers,—especially the Nile in the Eastern basin, and the Rhone in the Western. This has been found by the Author to be really the case—the percentage of Carbonic Acid in the entire amount of gas set free by the boiling of abyssal water in the Mediterranean being as high as 60, and that of Oxygen as low as 5, that of Nitrogen being 35; whilst the highest percentage of Carbonic Acid ever met with in the abyssal water of the Atlantic was 48, that of the Oxygen being 16. Thus it appeared that nearly the whole available Oxygen, in the abyssal water of the Mediterranean, had been used up by the decomposition of Organic matter; and this condition was quite sufficient to account for the extreme paucity of Animal life in the muddy deposit which is being formed by the very slow subsidence of the finest particles brought down by the great rivers and diffused through the entire mass of Mediterranean water.

Thus any deposit formed in a deep Inland Sea which is cut off from all but superficial communication with the Ocean outside, and into which a large quantity of Organic matter, as well as of Mineral sediment, is brought by large rivers, might be expected to be nearly or entirely *azoic*—Edward Forbes's limitation of Animal life to 300 fathoms being generally true of the Mediterranean, though not of the open Ocean.

The Temperature of the Red Sea is probably higher throughout than that of any other Inland sea,—the surface-temperature of its Northern part, even in January and February, being never beneath 70°, whilst in the Southern it rises in July and August sometimes to nearly 90°, and the Strait of Babelmandeb being so shallow that no water below 70° is likely to find its way into it from the Arabian Gulf. Temperature-soundings taken last February in the Gulf of Suez by Capt. Nares, gave *a uniform temperature* of 71° from the surface to the bottom at 450 fathoms. Hence it may be assumed with tolerable certainty, that even in the deepest part of the Red Sea, where the bottom lies at more than 1000 fathoms, the temperature will be never lower than 70°—thus contrasting very strongly with the temperature of the lower stratum of the Arabian Gulf, which, having a temperature of about 36°, must have come all the way from the Antarctic Sea.—In connexion with this high temperature of the Red Sea, it may be suggested as deserving of inquiry, whether the reef-building Corals live at a greater depth in it, than they do in the Pacific. The inquiries of Dana fully confirm the statement of Darwin, that these Corals do not live at greater depths than 20 fathoms; and they have also led him to the conclusion that they are limited in their distribution by the *isocheimal* of 68°. Now the question arises whether the limitation of Depth is not really determined by Temperature; and in that case these Corals should be found living in the Red Sea at greater depths than in the Pacific.

A curious contrast to this, however, is afforded by the Sulu Sea, an area lying between the N.E. portion of Borneo and Mindinao, only partly enclosed by islands at the surface, but shut in beneath by reefs which connect them. Now the surface-temperature of this sea, like that of the China Sea in its neighbourhood, is from 80° to 84°; and the temperature of both seems to fall at about the same rate through

the first 200 or 300 fathoms. But while the temperature of the Sulu Sea, which is 50° at 500 fathoms, never falls below this, even at 1600 fathoms, that of the China Sea, which is 51° at 200 fathoms, falls to 37° at the same depth. As the isocheimal of the Sulu Sea can never be any thing like as low as 50°, it is clear that the reduction of the temperature of its deeper portion to that standard must depend upon the entrance of cold water from the China Sea outside; and it may be pretty safely concluded that the depth of the channels of communication must be from 200 to 300 fathoms, so as to admit water of 50°, whilst excluding the deeper and colder stratum.

It is obvious that the existence of these peculiarities must have a very marked influence on the Biological conditions of Inland Seas—and that, as like peculiarities must have presented themselves in former periods of the Earth's history, the knowledge of them may afford important aid in the interpretation of Palæontological phenomena.

On the Tree Ferns of the Coal-measures, and their Affinities with existing Forms. By W. CARRUTHERS, *F.R.S.*

Lindley and Hutton describe two species of Tree Ferns from the Coal-measures, both from the Bath coal-field. I have been able to add eight species hitherto undescribed, chiefly through the assistance of J. M'Murtrie, Esq., of Radstock. These belong to three groups, which are remarkably distinguished by peculiarities in the structure of the stems. Two of the groups belong to living forms, while the third is extinct, being confined to Palæozoic formations. *Caulopteris* and *Tubicaulis* belong to the same type as the living ferns which possess stems, including under this term the humble stems (falsely called rhizomes) of many of our British species, as well as the arborescent ferns of warmer regions, and excluding the rhizomatous forms like *Pteris, Polypodium,* and *Hymenophyllum.* In all these stems we have a central medulla, surrounded by a continuous vascular cylinder penetrated regularly by meshes, from the margins of which the vascular bundle or bundles to the fronds are given off, and through which the parenchyma of the medulla is continuous with that of the stipes. In most tree ferns the medullary axis is larger, and the bases of the stipes decay down to the circumference of the stem; but in *Osmunda* the persistent bases of the stipes permanently clothe the small vascular cylinder, which encloses a slender pith. To this latter form belongs the stipe with a dumb-bell-shaped vascular bundle, separate specimens of which I have obtained from the Coal-measures. These have been described, both on the continent and in this country, under the name of *Zygopteris*; but they belong to Cotta's genus *Tubicaulis*, and they are very closely allied to a group of fern-stems which I have already placed together under the name of *Chelepteris.* The stem-structure of the common tree fern is represented by the genus *Caulopteris*, of which I have six species of carboniferous age.

The third and extinct group is represented by Corda's genus *Stemmatopteris*, only now known to be British, and by *Psaronius*, which, however, is not a separate generic form, but is only founded on specimens showing the internal structure of the stems of which Corda's genus is the external aspect. The chief characters of *Psaronius* have been drawn from the structure of the aërial roots which invest the stem, from which, indeed, the generic designation was derived; while the structure of the stem itself has been overlooked. But this is really of the first importance, as will appear from the following description which I have been able to make from a finely preserved specimen of an undescribed species in the British Museum, and from the figures of Cotta and Corda. The circumference of the stem was composed of a continuous envelope of indurated tissue; within this there were perpendicular tracts of vascular tissue never penetrated by any mesh. Between these tracts the leaves were given off in perpendicular series, the large single leaf-bundles coming right out from the central parenchyma, in which they existed as well-formed bundles, filling up more or less completely the medullary cavity. In one form (*Zippea*) the leaves are opposite, and the great proportion of the circumference of the stem is made up of the persistent and common vascular tissue; in others (species of *Psaronius*) the permanent elements of the stem consist of three, four, six or more perpendicular tracts.

The first two groups have the arrangement of the parts of their stems analogous to that which exists in the first year's growth of a dicotyledon. In both there is a parenchymatous medulla surrounded by a continuous vascular cylinder, which is perforated in regular manner by meshes for the passage-out of the vascular elements of the appendages. The stems of the third group have a structure analogous to that which is found in the stems of monocotyledons; for in both we have the vascular bundles of the appendages existing in the parenchymatous axis, and passing out independently of any closed cylinder. The permanent elements, however, of the circumference of the stems of *Psaronius* are without any analogue in monocotyledonous stems.

There seems, then, good reason for establishing two groups of ferns, with differences characteristic of their stems, comparable to those which distinguish the stems of monocotyledons from those of dicotyledons. But the caution I have always insisted on in dealing only with vegetative organs is specially required here; for I have discovered, I believe, the fruiting-fronds of one species of this group of plants. With the Bath specimens of *Stemmatopteris insignis*, Corda, as well as with those found on the Continent, the fronds of *Pecopteris arborescens* are always associated. It is the only fern found with some of the Bath specimens. It is also to be observed that the bases of the stipes correspond with the size of the leaf-scars on the stems. These facts are not absolutely sufficient for the correlation of the fronds with the stem; but they are the best evidence for this that we can expect in fossil botany short of actual organic union. Now the fruit of *Pecopteris arborescens* is so near to that of *Cyathea*, that I can find no characters whereby they can be separated. Our classification based on the stems must of course yield to that derived from the organs of fructification; and our group of ferns instead of being made into a new order, as it would be by some who publish on fossil botany, must be grouped with a tribe of recent *Polypodiaceæ*.

It may seem that this is a forced and arbitrary grouping together of plants that in some important characters so remarkably differ; and so it is, undoubtedly, to those who with rash confidence generalize on the systematic position of plants from stem-structure alone. But what can such objectors say to the practice of placing in close proximity plants that are beyond question nearly related to each other in all essential characters, though some have caudices (*Lastrea* &c.), while others possess rhizomes (*Pteris* &c.); yet these two forms of stems are more widely separated from each other than the stems of the extinct palæozoic group are from those of the recent forms.

On the present state of our knowledge in connexion with the Brachiopoda. By* Thomas Davidson, *F.R.S., F.G.S.*

In this brief notice Mr. Davidson referred to the attempts recently made to remove the Brachiopoda from the Mollusca and place them with the Annelides. Mr. Davidson still adheres to the view entertained by the larger number of zoologists, that the Brachiopoda form part of a class (*Molluscoidea*) independent of, but related to the Mollusca; he remarks, likewise, that some characters of the Brachiopoda are certainly very puzzling; but it must be borne in mind that any invertebrate group may be "annelidized" by overrating certain points of its affinities.

Mr. Davidson next alludes to the fact that the Brachiopoda are amongst the earliest known forms of animal life, and occupy, after the Trilobites, the most prominent place in the animalization of the globe. He then alludes to the many important researches made since 1853 in connexion with the anatomy of the animal, as well as with reference to the animal in life, especially by Messrs. Barrett, Lacaze-Duthiers, Jeffreys, Forbes, Dall, and others, and which would tend to show that the animal cannot extend its arms beyond the shell, is rather sluggish, and apparently insensible to light. In 1853 he laid before the public a review of what had been done by others as well as himself in relation to the classification of the Brachiopoda, proposing at the time to divide the class into about forty-five genera; but since then some sixty-nine additional genera had been proposed by twenty-four

* Printed *in extenso* in the 'Brighton Daily News' for August 20, 1872.

palæontologists; and if some fifteen or twenty of these be suppressed, the number will have been more than doubled since 1853.

Mr. Davidson observes that it is also curious to notice that a general, but not regular decrease in the number of species has taken place since the Palæozoic era up to the present time, and that many years must elapse before palæontologists will be able to clear away the many difficulties that still prevent their arriving at a truly satisfactory classification of the group.

Remarks on the Genera Trimerella, Dinobolus, *and* Monomerella. *By* THOMAS DAVIDSON, *F.R.S. &c., and* WILLIAM KING, *Sc.D. and Professor of Mineralogy and Geology in Queen's College, Galway.*

The paper touched upon some of the salient points treated of in a detailed memoir in preparation by the authors for the Geological Society. They propose the name *Trimerellidæ* for a family to include the genera named in the title. The typical genus *Trimerella*, although possessing many distinctive features, is in their opinion structurally and genetically related to *Lingula*. Reserving the discussion of the first of these points to their forthcoming memoir, they gave reasons for holding the view that *Trimerella* has been created, adopting the doctrine of genetheonomy, out of some preexisting Lingulid. The internal features, most complex in the type genus, were briefly noticed; and their modifications, as characteristic of the three genera, were pointed out.

The chronogeological range of the family extended from the Llandeilos to the Wenlocks, the latest and only representative species of *Dinobolus* occurring in the latter rocks. The known species have been found in Canada, the United States, Gothland, Russia, and England: Dudley is the only English locality. The family comprises about seventeen species, which have been instituted by Billings, Lindström, Hall, Meek, Dall, Salter, and the authors.

On the Physical Geography of the Mediterranean during the Pleistocene Age. By W. BOYD DAWKINS, *M.A., F.R.S.*

The geological evidence that the area of the Mediterranean has been subjected to oscillations of level during the tertiary period, is clear and decisive. Professor Gaudry has proved, in his great work on the fossil remains found at Pikermi, that the plains of Marathon must have extended far south into the Mediterranean, in the late Miocene period, to have supported the vast troops of Hipparions, herds of antelopes, and the very remarkable Mastodons and large Edentata which were revealed by his enterprise. The restricted and rocky area of Attica, as now constituted, could not have afforded sustenance for such a large and varied group of animals, nor could the broken hills and limestone plateaux of Peloponnese have been the haunts of the Hipparions and the Antelopes, if their habits at all resembled those of their descendants living at the present time. From this it follows that Greece was prolonged southwards, in the direction of Africa; and if Africa were then, as now, the headquarters of the antelopes, it is very probable that one of the lines by which they passed over into Europe was in this direction. In the Pliocene age, the presence of the Hippopotamus alike in Italy, France, and Germany can only be accounted for by the continuity of the African mainland so as to allow of the migration northwards of that animal. It would seem, therefore, that then also the area of the Mediterranean could not have formed the barrier to migration which it does now. But nevertheless the marine strata of Lower Lombardy, of Sicily, and of Marseilles prove that in some districts the present land was submerged during a part of the Pliocene age.

What was the physical geography of the Mediterranean during the Pleistocene age? The condition of Southern Europe at that time is an important factor in arriving at any true conclusions as to the Pleistocene climate in France, Germany, or Britain; for if it be proved that a mass of land then extended where the Mediterranean now rolls, the extension must necessarily have affected the heat of summer and the cold

of winter in Central and North-western Europe. I shall first of all take the evidence offered by the distribution of the Pleistocene mammalia of Southern Europe, and then compare it with the conclusions which may be drawn from the various soundings of the sea at the present time. We will begin with the mammalia of the Iberian peninsula. The researches of Captain Broome, Professor Busk, and of the late Dr. Falconer have established the fact that African mammalia, now no longer to be found in Europe, lived in the Pleistocene caves of Gibraltar. Besides the Lion, *Rhinoceros hemitœchus*, and Ibex, they discovered the Spotted Hyæna, and the Serval, both of which are peculiarly African species, and which must therefore have crossed over from that region to inhabit the caves in which they are found, or *vice versâ*. To this list a third African species is added by the African elephant, found, along with flint implements, in a river-gravel near Madrid. The last animal has also been obtained from the caves of Sicily by Dr. Falconer, in association with the Spotted Hyæna (the *Elephas antiquus*) and the Grizzly Bear, all of which were living at the time as far north as the latitude of Yorkshire. It is obvious that the presence of the African elephant in Sicily must have been brought about by the existence, in old times, of a bridge of land passing from Sicily to those districts which it still inhabits, just as the presence of the Grizzly Bear and *Elephas antiquus* in Sicily proves that they passed over from their European headquarters before the existence of the Straits of Messina. Nor are we without indications, from the study of the mammalia alone, of the position of the land which formerly connected Sicily with Africa. A small species of extinct Hippopotamus (*H. Pentlandi*), almost as small as the living *H. liberiensis* of Morton, occurs in such incredible abundance in the caves of Palermo, that its remains were formerly exported for use in sugar-refining. This animal has also been proved by Captain Spratt and Dr. Leith Adams to have lived in Malta, along with a pigmy elephant (*E. Falconeri*) and a curious gigantic dormouse (*Myoxus melitensis*); and it has also been met with in Candia; and more recently I was able to identify the last lower true molar of the animal among objects which Dr. Rolleston obtained from a Greek tomb at Megalopolis, in the Peloponnese, and which was probably derived from some of the many caves of the limestone in that district. For this extinct animal to have spread from Sicily to Malta, from Malta to Candia, and from Candia to the Peloponnese, or *vice versâ*, the whole of these islands must have been united together, and must have formed the higher grounds of a land that is now sunk beneath the waves of the Mediterranean.

This was Dr. Falconer's opinion; and it is fully borne out by the soundings, which prove that a comparatively shallow sea now separates the Peloponnese from Candia, and Sicily from Malta, and the adjacent mainlands of Italy and Africa. The great depth of the sea, no less than 1400 fathoms, which intervenes between Candia and the mainland of Tangier, offers a difficulty to the view that the land has been sunk to that depth since *Hippopotamus Pentlandi* lived in the island; and it is therefore very probable that the animal found its way from Sicily and Malta by way of Peloponnese, rather than over an extension of the African mainland. The soundings reveal the fact that the Mediterranean consists of two deep basins, separated from each other by comparatively shallow water, one barrier extending from Africa, past the Straits of Gibraltar, to Cadiz, and the other reaching from Tunis, past Sicily and Malta, to join Italy. The elevation of these barriers above water would satisfactorily account for the presence of African mammalia among the European fauna of the Pleistocene; and we may therefore reasonably conclude that they were then above water. In that case, however, the Mediterranean would consist of two small land-locked basins, around which there would be comparatively free migration from Africa to Europe, and *vice versâ*. In the map exhibited I have represented the restricted area which the Mediterranean must necessarily have occupied if the land were elevated to the extent of 400 fathoms, or the depth between Candia and Peloponnese. The substitution of a mass of land such as this for a stretch of sea in the Mediterranean area, could not fail to cause the summer heat to be more intense in France, Germany, and Britain than it is now, while the increased elevation of the land, to an extent of 2400 feet, would produce a corresponding intensity of winter cold, as Mr. Godwin-Austen has pointed out in the case of the hills of Devonshire. And it must be admitted that this condition of things would react on the climate of France and Germany, and even of Britain. When,

indeed, we consider that the Pleistocene land-surface extended from Africa northwards as far as the hundred-fathom line, to say the least, in the Atlantic off the coast of Ireland, it is no wonder that the African animals, such as the Spotted Hyæna and the *Felis caffer*, should have ranged as far north as Yorkshire; for the only barrier would be that offered by the severity of the Pleistocene winter. The Hippopotamus and the Striped Hyæna found in the caves of Lunel-Viel and of Spain cannot be cited as evidence of a continuity of land between Africa and Europe in the Pleistocene age, because they were European Pliocene species, and may therefore, like the horse, have lived on into the succeeding age without any migration.

On the Fossil Animals of Mount Leberon (Vaucluse). By Professor ALBERT GAUDRY.

The author stated that he had made excavations near Cucuron in Mount Leberon, where Christol, Gervais, and others had already made some researches—and that he had there obtained about 1200 bones, which are deposited in the Museum of Natural History at Paris. The following is a list of species obtained:—

Machairodus cultridens.
Ictitherium hipparionum, or *Ic. robustum.*
—— *Orbignyi?*
Hyæna eximia.
Dinotherium (a very large species).
Rhinoceros Schleiermacheri.
Acerotherium incisivum?
Hipparion gracile.
Sus major.
Helladotherium Duvernoyi.
Tragocerus amaltheus.
Garnella deperdita.
Cervus Matheronis.
Testudo (a very large species).
Testudo (a small species).

All of these species, except *Cervus Matheronis* and *Testudo*, had been found by the author at Pikermi in Attica. In comparing the 1200 bones from Mount Leberon with the 4940 bones from Pikermi, the author had been struck with the variations exhibited by animals that seem to have descended from the same parents. He also noticed that the presence of numerous herbivores, such as *Hipparion*, *Tragocerus*, and *Garnella*, and of one so large as *Helladotherium*, proves that a great extent of meadow-land and a varied scenery must have existed at the end of the Miocene period.

The author considered that the fossils of Leberon are somewhat more recent than those of Eppelsheim, but about the same age as those of Pikermi in Greece, Baltaver in Hungary, and Concud in Spain. The age of the beds in which they occur at Mount Leberon is very clearly seen from the following Table:—

7. Terrestrial beds, with bones of *Hipparion* and other animals.
6. Lacustrine marls, with *Helix Christoli.*
5. Marls with *Ostrea crassissima.*
4. Littoral marine beds, with *Cardita Jouanneti* and other fossils, as at Salles.
3. Yellow Mollasse, with *Ostrea Boblayi* and *Pecten planosulcatus.*
2. Grey Mollasse; fossils rare or absent. Probably found in a deep sea.
1. Neocomian beds.

On the Prospect of finding Productive Coal-measures in Norfolk and Suffolk, with Suggestions as to the place where an Experimental Boring should be made. By the Rev. J. GUNN, *F.G.S.*

Mr. Gunn showed that the Anglo-Belgian Basin had existed from the Forest-bed period to that of the Palæozoic rocks, that it was bounded by such rocks on the east and the south, that a remnant at Harwich indicated that such also was its boundary to the west, that it was open to the sea to the north, very favourably to the formation of coal—that there was proof of the existence of forests in this basin, which had been repeatedly elevated and depressed at various times, and that the seams of coal on the Belgian side were proved to have increased, rather than thinned, as they approached the coast. On these grounds Mr. Gunn thought an experimental boring was desirable; and he fixed upon Hunstanton, because the

work would commence there with a lower bed than was reached at the Norwich boring, namely the Kimmeridge clay, and, from the absence of the next stratum (the Coral-rag), and thinning-out and absence of others, he did not anticipate a deeper bore than 1000 feet before coal would be obtained.

On the occurrence of Trunks of Psaronius *in an erect position, resting on their original bed, in Rocks of Devonian age in the State of New York; with some Inferences regarding the Condition of the Sea-bottom and Shore-line during the Deposition of the Strata. By* Prof. JAMES HALL.

During the year 1870 some excavations were made in Schoharie County, N. Y., in beds of sandstone, referred at that time to the upper part of the Hamilton group, but which probably belong to higher beds in the series. Several trunks, apparently of tree ferns, were found in an upright position, with their bases resting in and upon a bed of clay, in which they appear to have grown. In this clay, and in the lower three feet of the sandstone above, there were abundant remains of vegetable substance, supposed to belong to these trunks and to other vegetation of the period. Principal Dawson refers these trunks to the genus *Psaronius*; and he has determined two or more species from the locality.

The author believed that here we had evidence of a point of comparatively dry land on the eastern margin of the Devonian sea. In tracing the beds westwards, it was found that at first coarse sediment predominated with but few fossils except plants; but in going in a westerly direction the sandstones lose their coarseness, the shales become finer and calcareous. A corresponding change takes place with the fauna; for at first, where shells occur, they are chiefly those of the Lamellibranchiata, and it is not till we have travelled some distance to the westward that Brachiopoda are found, at least in any quantity. Where both occur, the Lamellibranchiata are confined to the harder and coarser beds, and the Brachiopoda, as a rule, to the finer sediments. Not only so, but sometimes the coarser beds are charged with a few species of particular genera, as of *Aviculopecten*, while others are crowded with *Modiola*-like forms with few *Aviculopectens*; whilst *Grammysia*, a genus which may perhaps belong to the Unionidæ, has sometimes flourished abundantly, to the almost entire exclusion of every thing else.

The changes here indicated can be traced over a line of outcrop of more than three hundred miles from east to west, and through a vertical thickness of from two to four thousand feet.

The author inferred that this area during the deposition of these beds was undergoing continuous oscillation of level, with a general downward movement. He considered that the alternation of coarser and finer beds, with their characteristic fossils, might be due to such oscillating movements.

On the Relations of the Middle and Upper Silurian (Clinton, Niagara, and Lower Helderberg) Rocks of the United States. By Prof. JAMES HALL.

The author remarked that although American geologists still use the local terms applied to the various divisions of Palæozoic rocks by the Geological Survey of New York, yet the relations of these divisions to the greater divisions in use in England have been carefully studied. The grouping adopted by the author is as follows:—

UPPER SILURIAN	Lower Helderberg. Water-lime.
	Onondaga Salt group, or Salina formation.
MIDDLE SILURIAN	Niagara group. Clinton group. Medina Sandstone.
LOWER SILURIAN	Hudson-River group. Trenton, Black-River, Birdseye } Limestones.

Below all these come the well-marked Lower Silurians, the equivalents of the British Caradoc and Llandeilo formations.

Between the Middle and Upper Silurians of the United States there is scarcely a single species in common. Representative species occur; and whenever the physical conditions have been similar during the two epochs, the species occurring in those beds bear a close similarity to each other.

The author alluded to the opinion of Mr. Warshen, that the Lower Helderberg group should be placed with the Niagara group, and expressed his strong dissent from those views. He traced these rocks for several hundred miles in their westerly range from the Schoharie valley, and said that in that direction the Lower Helderberg group dies out, whilst the Water-lime and the Onondaga Salt group considerably expands. To the east and south of the Schoharie valley the Lower Helderberg group always occurs, and is everywhere underlain by the Water-lime formation. In Canada the Lower Helderberg group is largely developed, whilst the Niagara group scarcely exists there.

The author contended that throughout all this vast area the physical fact of superposition and the evidence of fossils coincide to prove the Lower Helderberg group a distinct and overlying formation to the Niagara group, and separated from it by the Onondaga Salt group and Water-lime formations, wherever these latter formations exist.

It appears, however, that in parts of Tennessee the Lower Helderberg and Niagara groups do sometimes come into contact from the local thinning-out of the intermediate groups. But upon this Prof. Hall remarked that while the actual physical and zoological distinction can be traced in a westerly direction for more than twelve hundred miles, in a north-easterly direction for six or eight hundred miles, and for an equal distance in a southerly and south-westerly direction, he could scarcely suppose that the few facts observed within limited areas, and not yet submitted to the test of comparison, would change the views of geologists upon the distinctive character of these formations.

On the Chalk of the Paris Basin.

By M. Hébert, *Professor of Geology in the Sorbonne, Paris.*

This communication was made by M. Hébert, as the result of his researches on the Chalk of the Paris basin. It was illustrated by two sections, the first of which represents the cliffs of the channel from Havre to Boulogne, the second giving a section from Le Perche, a district which borders Brittany on the east, to Belgium. The characters which, according to M. Hébert's classification, divide the beds are so well marked, that it is possible to ascertain the point where one division ends and another begins. At this point not only does the fauna change abruptly, but also the lithological differences are equally clear; besides, the surface of one division is always hardened and eroded more or less. There is no passage of the lower-lying hard beds into the soft upper chalk. These lines of separation are always more numerous than the palæontological divisions; but two palæontological divisions are always unconnected. These characters, in M. Hébert's opinion, remove all difficulty; and in submitting the results of his researches to those English geologists who interest themselves in the chalk, he hopes to convince them of the exactitude of the divisions he has proposed; and he would refer them to the cliffs of Kent, which afford an exact copy of those of the opposite shore of France.

The divisions which M. Hébert has established are as follows in ascending order:—

1. Glauconitic chalk, the equivalent of the Upper Greensand and grey chalk.
2. Chalk with *Inoceramus labiatus*, or chalk marl, and chalk without flints, and a portion of the chalk with flints.
3. Chalk with *Micraster cor-testudinarium*, having for its base the zone of *Holaster planus*, and which corresponds to a portion of the chalk with flints.
4. Chalk with *Micraster cor-anguinum*, chalk with flints.
5. Chalk with *Belemnitella mucronata*, Norwich Chalk.

The Chalk of the Paris basin forms several parallel folds, which correspond

with orographical accidents. Traversing the country from Artois to Brittany, they form elevations and depressions in the following order:—1. The axis of elevation extending from the Boulonnais to the Ardennes (axis of Artois of M. Archiac). 2. Depression corresponding to the valley of the Somme formed in the most recent beds, viz. Chalk with *Micraster cor-anguinum*, which extends from St. Valery sur Somme, passing by Amiens, Longueau, and Moreuil, where it meets the chalk of Meudon in the direction of Noyon. 3. The second axis from Compiègne to Breteuil, which extends by the valley of La Bresle as far as Tréport, which opens out in the lower portion so as to show in the bottom of the valley the chalk containing *Inoceramus labiatus*, and on the flank the newer beds dipping in the opposite direction. 4. Between this upheaved portion and that of Bray there is a depression which can be followed from Criel-sur-Mer to Beauvais. 5. The axis of upheaval of the district of Bray is seen on the shore of the English Channel at Biville-sur-Mer. There the *Craie Glauconieuse* is visible at low water. There are several faults which are visible in the cliffs. This upheaved portion is much larger than the preceding one, and is seen as far as Dieppe, where it ends, being cut off by a fault of about 200 feet. 6. A very well-marked depression exists between Dieppe and Fécamp, of which Veules occupies the centre. There the chalk with *Micraster cor-anguinum* descends to the level of the sea, while both at Fécamp and Biville the Craie Glauconieuse is at the same level. This depression runs parallel to the axis of the district of Bray as far as Gisors, where the chalk of Meudon is seen at a much lower level than the older beds found to the N.E. or S.W. 7. The ridge extending from Fécamp to Meudon, by Rouen and Vernon. This elevation is accompanied by a fault which, though in a somewhat broken line, still keeps a course parallel to the general direction of the river Seine from Paris to Rouen. The sections show that the strata have been raised on each side towards the fault between Rouen and Mantes; and consequently the valley of the Seine does not correspond to a depression which would be the counterpart of the elevation of Bray. The Seine winds in and out, crossing the fault repeatedly. Beyond Mantes the fault passes to Beynes, and is prolonged to Meudon, Bicêtre, &c., where the chalk is elevated and probably takes the form of an upheaved fold. 8. To the south-west of the projecting mass of Beynes and Meudon a large depression exists, which seems to take in the valley of the Eure as far as Louviers, and accounts for the presence of *Calcaire grossier* in this outlying portion of the tertiary basin. 9. To the south-west of this zone, which extends from Trappes to Caudebec, the strata are upheaved, and the chalk with *Inoceramus labiatus* is seen at the foot of the hills of Le Perche. The sandstones of Maine crop up from under this chalk and form this new upheaved fold, which has several flexures, and is followed by the fault which extends from Nogent le Rotrou.

Thus (1) Le Perche, (2) the axis of the Seine, (3) the district of Bray, (4) the axis of La Bresle, (5) the axis of Artois from the Boulonnais to the Ardennes, form five convex folds which are parallel and separated by depressions. They have been produced by the general movements of the Paris basin, due to the contraction of the earth's crust. These folds are of earlier date than the "Argile rouge à silex" (red clay with flints), which covers up the eroded surfaces of the different beds of the chalk, with the exception of the chalk with *Belemnitella mucronata*, which is probably of more recent origin; for the lignites and the lower sands repose at Veules, Varangéville, Criel, and St. Valery-sur-Somme on the chalk with *Micraster cor-anguinum*. If denudation had taken place, it would not be accounted for by supposing that the chalk with Belemnites was entirely removed elsewhere; the folds could have been augmented at a later period.

The two sections show the perfect correspondence of the several folds; but their regularity is shown by all the observations made. They approach each other towards the north-west, and do not extend to the south-east beyond a line passing through Paris from south-west to north-east. The folds are much nearer to each other on the coast-line than inland, where they are separated twice as much.

Now, what becomes of these folds on the English coast? It is certain that the fifth and last of them, the axis of Artois and the Boulonnais, corresponds to that of the Weald, and equally so that the Jurassic coast-line of Portland corresponds

with that of Hennequeville, near Trouville, which seems to belong to the "Perche" system, and of which the Havre beds are an extension. The second fold seems to point towards the Isle of Wight, where another dislocation from east to west seems to have crossed it. The third and fourth, those of Bray and La Bresle, do not appear to extend to the Hampshire basin.

Parallelism of the French and English Chalk.—The English chalk, taking the chalk of the Kentish coast from Folkestone to St. Margaret-on-Cliff as the type, would be thus grouped so as to correspond with the divisions established by M. Hébert in France.

I. Taking the Gault as the base of the chalk, on which point all are agreed, the 1st division of the chalk would be formed by the Upper Greensand, "grès vert supérieur," which is the same at Folkestone, Havre and Fécamp, and elsewhere. The grey chalk (*craie grise*) which covers it is identical with that of Rouen; the *Ammonites varians, Mantelli,* and *rhotomagensis* which are there found, leave no doubt; and it is recognized that in France the same fauna exists in the Upper Greensand and the grey chalk, and that these two rocks alternate. These two divisions would form one, as *La Craie Glauconieuse.* There may be some difficulty in separating the grey chalk from the chalk marl.

II. The grey chalk is covered at Folkestone as in France (generally) by a very nodular chalk without flints, and with grey argillaceous veins, containing *Inoceramus labiatus* (Brongniart), *Ammonites nodosoides* (Schluter), *Echinoconus subrotundus,* &c. This forms the second division of the chalk. The difference of the fauna of this from that of the underlying bed is almost complete. Sometimes, as Mr. Whitaker has observed, and has kindly furnished M. Hébert with his views, at the base of this nodular chalk is an argillaceous bed with Belemnites, which is most likely the *B. plenus* of Blainville. This bed is found in Shakespeare's Cliff, and has also been recognized in France in several places, more especially at Neufchatel in Bray and Boulogne. It forms the base of the division termed Craie à *Inoceramus labiatus.* The junction of this bed of argillaceous chalk with the underlying grey chalk will be found to be marked by a hardened and eroded surface, which is pierced by holes.

At Dover the thickness of the chalk without flints, with *Inoceramus labiatus,* may be considered from 125 to 140 feet, to which should be added about 80 feet of the chalk with flints lying above it in the eastern cliffs of Dover, as they contain exactly the same fauna. This division, like the former, is always terminated by one or more hardened and pierced surfaces.

III. The next 135 feet in thickness consist of a series of hard nodular beds, containing beds of flint, the principal fossils of which are *Holaster planus* (in the lower part) and *Holaster placenta* (above); *Ananchytes gibba* is also very common, as well as *Micraster cor-testudinarium,* which gives the name to this division. The lithological character is also well marked. It is seen just at the cliff to the south of St. Margaret, at the level of the sea, and is there rich in fossils.

IV. Above the last-named hard chalk, a soft chalk, often quite of a mealy aspect, forms the upper part of the northern cliffs of Dover and the whole of the cliff north of St. Margaret. This should be referred to the chalk with *Micraster cor-anguinum,* abundant at Gravesend, but badly preserved at St. Margaret.

V. A division characterized by the presence of *Belemnites mucronatus,* does not exist in Kent, but only in Norfolk.

It is very important to observe that each of the principal limits assigned to these divisions corresponds in France with the places of thick beds which are wanting in England. Thus between the *Craie Glauconieuse* and the chalk marl with *Inoceramus labiatus,* the great series of the sandstones of Maine and the limestones with Ichthyosarcolytes is interposed. These beds are absent in the north of France and Germany, as well as in England; also between the chalk marl with *Inoceramus labiatus* and the chalk with *Micraster cor-testudinarium,* as described above, the great mass of the hippuritic limestones should be placed. This also does not occur in the northern countries. These remarks prove that the stratigraphical limits which have been described indicate great breaks in the sequence, of long duration, when no remains were deposited in the north of Europe.

On the Cambrian and Silurian Rocks of Ramsey Island, St. David's. *By* Henry Hicks, *F.G.S.*

In a Report to the British Association in 1866 by the late Mr. Salter and the author, Ramsey Island was mentioned as a part of the district which had been examined, and a short description of the rocks exposed there was also given. Since that time the author has had several opportunities of further examining the island, and this year in conjunction with Messrs. Homfray, Lightbody, Kirshaw, and Hopkinson.

During these researches all parts of the strata have been very carefully examined; and the results have been highly satisfactory. The best section occurs at the north end of the island; and the following formations occur there in succession, beginning on the east side:—

1. *Lingula-flags*, a series of hard siliceous sandstones, with grey flaky slate, about 600 feet in thickness, and containing *Lingulella Davisii* in great abundance, but no other fossils, save worm-tracks and burrows, and some plant-like markings.

2. *Tremadoc group*, or, rather, a thick series of beds holding in the succession relatively the same position as the Tremadoc rocks do in North Wales. These beds graduate by almost insensible degrees from the Lingula-flags, first as bluish-grey flag, and then earthy grey thick-bedded rock, and assume at the upper end an appearance approaching to that of the overlying beds of the Arenig group. They have a thickness of from 800 to 1000 feet; and fossils are very abundant throughout the whole series. The species are nearly all new, and also many of the genera. A list of the fossils includes four species of Brachiopods, ten species of Trilobites, *Orthoceras* two species, *Ctenodonta* two species, a *Theca*, *Bellerophon*, Encrinite, and a Starfish, the latter discovered for the first time this year by Mr. Lightbody. In this fauna, as in the Tremadoc rocks of North Wales, some of the forms are primordial in character, others of a Silurian type; and there are several which had not previously been known to exist in rocks of so early an age. With the exception of the rocks in the neighbourhoods of Portmadoc and Dolgelly, we do not know of any deposits of the same age in Britain; and, indeed, until the discovery of these beds at Ramsey Island, and some other places in the neighbourhood of St. David's, they were not supposed to extend beyond those districts.

3. *Arenig group.*—Iron-stained slates and flags, interlined by felspar lines and felspathic ashes. They have a thickness of about 1000 feet, and lie nearly vertical. They occur in succession to the Tremadoc group, and in true conformability. Trilobites of the genera *Asaphus*, *Ogygia*, *Æglina*, *Trinucleus*, *Ampyx*, *Calymene*, and *Agnostus* occur in them along with *Conularia*, *Bellerophon*, *Theca*, *Orthoceras*, *Lingula*, and *Orthis*, and, as shown by Mr. Hopkinson, also no less than twenty-two species of Graptolites of various forms.

In this section at Ramsey Island the succession from the Cambrian rocks to the Silurian is, the author believes, better shown than at any other known place in the British Isles.

On the Graptolites of the Arenig Rocks of St. David's. *By* John Hopkinson, *F.G.S.*, *F.R.M.S.*

In the lowest beds of the Silurian rocks at St. David's the author had found a considerable number of Graptolites, which, he thought, proved the equivalency of these beds with the Quebec group of Canada, the Skiddaw slates of Cumberland, and the Arenig rocks of Shelve.

The Graptolites, of which more than twenty species have been determined, were found at Ramsay Island and Whitesand Bay, in the lower part of a series of black shales about 1000 feet in thickness, which, from their position and from the evidence afforded by the fossils they had previously yielded, had already been inferred to be of Arenig age.

Of the true Graptolites or Rhabdophora the genera *Didymograpsus*, *Tetragrapsus*, *Loganograpsus* (?), and *Phyllograpsus* occur. All are Quebec and Skiddaw forms, *Didymograpsus* alone passing into higher rocks. The Graptolite allies are represented by the genera *Ptilograpsus*, *Dendrograptus*, *Callograptus*, and *Dictyonema*.

These have a more extensive range, *Dictyonema* lasting from the Cambrian to the Devonian period; but until now they were only known to occur together and in any abundance in the Quebec rocks of Canada. They have, however, recently been discovered by the author in the Arenig rocks at Shelve. A few specimens, apparently referable to the genus *Retiolites*, have also been found. This genus begins in the Quebec group (Arenig), and ranges upwards to the highest beds of the Caradoc or Bala rocks.

Of the species many are new; but all hitherto described are entirely restricted to the Arenig group. All these occur in the Canadian rocks; but only two (*Didymograpsus patulus* and *Tetragrapsus serra*) have previously been recorded from the Arenig rocks of Britain. The entire Graptolite fauna is thus, in its species as well as in its genera, more nearly allied to that of the Canadian Arenig rocks than to our own Arenig faunas in Cumberland and Shropshire.

The species, of which specimens were exhibited, are as follows:—

Didymograpsus extensus, *Hall*.	Dendrograptus arbuscula, sp. nov. (*Salter*, MS.).
—— patulus, *Hall*.	—— divergens, *Hall*.
—— pennatulus, *Hall*.	—— flexuosus, *Hall*.
—— plumula, sp. nov.	—— pumilus, sp. nov.
—— sparsus, sp. nov.	—— striatus, *Hall*.
Tetragrapsus serra, *Brongn*.	Callograptus (?) diffusus, *Hall*.
Loganograpsus (?) implicatus, sp. nov.	—— elegans, *Hall*.
Phyllograpsus stella, sp. nov.	—— radiatus, sp. nov.
Retiolites ensiformis (?), *Hall*.	—— radicans, sp. nov.
Ptilograpsus cristula, sp. nov.	—— Salteri, *Hall*.
—— Hicksii, sp. nov.	Dictyonema cancellata, sp. nov.

A specimen of *Callograptus radiatus*, with an entire "hydrocaulus," or main stem, and a "hydrorhiza," the organ of attachment, was specially alluded to as furnishing an important addition to our knowledge of the mode of growth of the dendroid Graptolites. The hydrorhiza appeared as a series of interlacing or anastomosing fibres, which must have formed a kind of network over the surface to which it adhered. Its presence in this specimen was considered to prove it to be an essential organ of the genus *Callograptus*, its rarity being accounted for by its perishable nature, and the probability of the Graptolite being almost invariably severed from the substance to which it was attached at the junction of the hydrocaulus with its hydrorhiza.

The other dendroid Graptolites (*Ptilograpsus, Dendrograptus*, and *Dictyonema*) were also shown to have been most probably fixed forms.

On the Minerals lately found in the Drainage-works at Brighton. By James Howell.

The author exhibited curious and beautiful specimens of minerals found in the north-west portion of Brighton, the Montpellier district, during the excavations for the main sewer. These excavations were carried through beds overlying the chalk, down into the chalk itself, to a depth of from 22 to 30 feet. The surface-beds consisted of vegetable mould, loam, and brickearth, the latter reaching in many places to the depth of 17 feet. Imbedded in this deposit were masses and veins of Websterite, mingled with brecciated masses of ironstone, flints, gypsum, and indurated clay, frosted over and permeated with crystals of selenite, varying in form and colour, and presenting a beautiful appearance. There were also tabular flints, probably a silicate of iron about $\frac{3}{4}$ of an inch in thickness, coated with a carbonate of lime, with nodular flints shivered in every direction, and recemented by the Websterite. Some of the breccia, lying at the depth of 17 feet, so much resembled "slag" as to deceive the eyes of good mineralogists. Most of it had undergone intense chemical action, as if the gases had bubbled up and escaped, leaving orifices upon the surface, or presenting a botryoidal aspect. Some of the ironstone presented a honeycomb appearance, being of a black or dark

purplish colour, spangled with pretty star-like crystals of selenite. Other specimens exhibited contained a high percentage of that useful metal, as much as from 55 to 60 per cent. Limonite, too, was abundant. Beneath the ironstone, in a deposit resembling yellow ochre, probably an oxide of iron, lay a curious formation containing much iron, gypsum, and indurated clay, with seams of selenite of a dark green and purple colour. When broken, this stone was found to be beautifully variegated, and was susceptible of a high polish. The selenite was so compact in the heart of this formation as to make the eye take it for quartz; and one gentleman could not be convinced to the contrary till he scraped it with his penknife. Flints and iron and indurated clay were everywhere frosted over and intercalated with every form and variety that the crystals of selenite could assume, forming magnificent specimens of nature's workmanship for either the museum or the drawing-room.

The author next gave a detailed description of the discovery, history, and composition of Websterite, displaying some fine specimens, and stating that there were still finer ones in the British and Brighton Museums. About 3 feet from the surface of the road in Powis Villas, the workmen discovered what had every appearance of the petrified trunk of a tree, the bark being changed into lignite, and the woody structure into a white fibrous substance, with medullary rays verging from the centre. Two fine specimens of this, in the Brighton Museum, were first marked as "fossilized trees." Upon analyzation, however, by Dr. Flight of the British Museum, the fibrous substance proved to be Websterite, and the ligneous-like coating manganese with a small proportion of cobalt. Testing it with hydrochloric acid also reveals the presence of a carbonate, whether of lime, alumina, or some other substance the author does not know. The Websterite lying in the clay or brickearth was in a very friable state, of a milk-white colour, and which might be mistaken by the eye for magnesia. Other specimens were more compact and of a straw-colour; and in the core of one of these specimens lay imbedded what appeared to be very like a small, smooth, dark-coloured flint; but flint it was not, but the same substance probably coloured either by manganese or iron. Another pretty specimen in the mineralogical department of the Brighton Museum has a beautiful straw-coloured coating of what analyzation might prove to be allophane.

Mr. Howell then entered into the origin of the specimens exhibited, stating that observations had convinced him that it was chemical agency, and that such was as active now in the beds above the chalk in the Montpellier district at Brighton and elsewhere as ever it had been during the deposition of the Eocene strata, to which these beds geologically belonged.

On Super-Cretaceous Formations in the Neighbourhood of Brighton. *By* JAMES HOWELL.

This paper was the result of observations made by Mr. Howell during the progress of the excavations for the purpose of draining the town of Brighton in the years 1870 and 1871. According to Mr. Howell, the town of Brighton stands upon six distinct formations:—

1. Chalk with flints, upon the crests of the hills and their abrupt descents.
2. Lower Eocene, constituting Furze Hill.
3. Temple Field deposit, formed of the ruins of the Eocene and Chalk strata. In the Montpellier district, sloping down the western hill towards Furze Hill and Hove Level.
4. Postpliocene, Brighton cliff formation, Coombe rock or Elephant-bed, chiefly East Brighton, especially the cliffs at Black Rock, also the base of the silt in the Brighton valley.
5. Postpliocene brickearth, resting on Coombe rock or sand. Hove and Western Brighton.
6. Recent. Silt of the Brighton valley.

Leaving the Cretaceous strata, so ably explored and so graphically described by Dr. Mantell, the author drew attention to Furze Hill as one of the remnants left

by denudation of the plastic clay in Sussex, first determined by Sir Roderick Murchison in 1850, but more thoroughly investigated by Mr. Montague Phillips in 1851, who found it to consist of layers of marl and clay, the upper part composed of comminuted marine shells, the clays being of various colours, a bed of lignite, 4 feet thick, containing much sulphur, analogous to that found in the Paris and Hampshire tertiary basins. Faint impressions of dicotyledonous trees were also detected upon the clay. Mr. Phillips also discovered a cluster of fossil fruits of an unknown species, intermediate between the Brazilnut and Walnut, with crystals of selenite among the clays, and a thin vein of subsulphate of alumina in an outcrop of what he considered the same formation at Prestonville. Patches of the lower Tertiaries are to be seen here and there over the whole area of the South Downs, whilst scattered over their surface are water-rolled specimens of the breccia forming the base of the tertiary deposits at Seaford and Newhaven, together with "grey weathers" or druid sandstones; while within 200 or 300 yards of the Eocene strata at Furze Hill, the excavations for draining the town of Brighton revealed the ruins of the plastic clay once lying *in situ* in that locality, consisting of clays and sand, breccia of angular flints impregnated with iron, ironstone, gypsum, subsulphate and hydrate of alumina, loamy deposits, crystals of selenite, and ferruginous chalk-rubble. The upper portion of this heterogeneous mass consists of a chocolate or yellowish loam, and in many places, where the chalk immediately underlies it, of ironstone or breccia impregnated with iron, in which case the subcretaceous strata are in every stage of decomposition. The loam contains chalk-like granules, which, on being exposed to atmospheric action, crumble into a fine ochraceous powder. This is probably effected by the percolation of water highly charged with acids derived from the soil, iron, or decomposing iron-pyrites, which, like a disease, eats deep down into the core of the chalk, and eventually converts it into the ochraceous tree-bearing loam, such as forms the soil of the Montpellier district and of the copse by the roadside to the dyke. The clays or brickearth, if it be such, the author believes to be of a date anterior to that lying in the Hove Levels. The breccia, in immense masses, lies mingled with the clays and chalk-rubble as if it had been torn from its bed by some mighty force. Hundreds of tons were extracted from an excavation 2 feet 6 inches in width at the bottom of Clifton Hill at its junction with Montpellier Road up to St. Michael's Place, where it lay piled up like a wall to the height of 5 feet. This interesting section was showed upon the plan which the engineer of the works, Mr. Good, kindly prepared for the author. Much of this conglomerate has undergone intense chemical action, some specimens being scarcely recognizable from "slag." Many of its cores are ornamented with calcites, crystals of selenite, and gaseous botryoidal bubbles coated with a delicate bloom of violet, yellow, and green. The subsulphate and hydrate of alumina lie in veins and masses imbedded in the clays, from a milk-white powdery substance up to the consistence of gypsum. One specimen assumed the form of a trunk of a tree; its lignite-like coating, on being analyzed by Dr. Flight, of the British Museum, was, however, found to consist of manganese, together with a small proportion of cobalt. Far from being a scarce mineral, the author described it as being plentifully spread over the chalk-districts wherever ironstone or iron-pyrites was superimposed upon clay. Specimens of the tree-like variety the author had extracted from chalk in which it was completely isolated, the chalk matrix showing no signs of decomposition. He had found portions of clay, too, similarly isolated in chalk-strata with no appearance of rents or fissures; and the questions were, How got the clay there? and how was the subsulphate of alumina formed?

Mr. Howell, in describing the Coombe rock or Elephant-bed, drew attention to the cliffs at Black Rock, consisting of this peculiar deposit superimposed upon an old sea-beach lying from 12 to 15 feet in the cliff above the present one, finer sections for inspection being nowhere visible. Sir Roderick Murchison and Mr. Godwin-Austen state that brickearth is the equivalent of Coombe rock, both being of the same age; but the observations of the author during the excavations through the town of Brighton prove Coombe rock to be the older deposit—brickearth, when present, everywhere overlying it, in the same manner as Coombe rock overlies the chalk. The equivalent of Coombe rock, therefore, was not brickearth, but chalk.

rubble, which was the same formation with a less admixture of clays. Bones and teeth of the Mammoth, the Horse, Ox, Deer, and Whale, &c. were found imbedded in the two deposits, which showed that they were not far removed from each other in geological sequence. In speaking of the old sea-beach, the author doubted its existence, as stated by Mantell, 50 feet beneath the surface of the Western Road, which consists almost entirely of chalk from its commencement to Western Cottages, where the Coombe rock makes its appearance, followed by brickearth, which there overlies it. Mr. Howell inclines to the opinion that the clays of the Coombe rock and brickearths, as well as the lignite, breccia, and sandstones of the former deposit, were derived by denudation from the tertiary strata of the South Downs, in the same manner as those tertiaries might have been derived from the denudation of the Wealden.

Coming down to the recent periods, the author described the Brighton valley as consisting of silt and flints resting upon Coombe rock, in which were imbedded immense quantities of water-rolled sandstones, similar to the "grey weathers," the whole deposit pointing to a time when the valley was an estuary of the sea as high up as the London and Lewes Roads, then the beds of rivers, one possibly issuing from the Weald, the other probably from the high hills round about the village of Falmer. Pebbles, exactly the same as those lying on the Brighton beach, were dug up at a depth of 11 feet in the valley, above the new church, lying in Coombe rock, which had every appearance of having been the bed of a stream. Few or no specimens of palæozoic pebbles were met with similar to those in the old sea-beach, the author inclining to the views of Mr. Godwin-Austen, of a coast-line extending from Colvados across the Channel to Sussex in Postpliocene times, dry land being to the east of this coast-line, whose beach was the same as that now found in the Brighton cliffs, along which the palæozoic pebbles found in the old sea-beach travelled from France, giving illustrations of pebble-travelling that came under his own observation in the Isle of Wight.

On the Trachyte Porphyries of Antrim and Down, in the North of Ireland. By Professor Edward Hull, *M.A., F.R.S., F.G.S., Director of the Geological Survey of Ireland.*

Trachyte is one of the rarest of the British rocks, and it is as yet uncertain whether it is to be found amongst these islands except in the north of Ireland. In this district it was identified by the late Professor Jukes and Mr. Du Noyer during the progress of the Geological Survey in the year 1867. Under the name of "clay-porphyry" of Sandy-brae, it is described by Dr. Berger in his paper "On the Geological Features of the North-east of Ireland"*; and the author gives a short account of its characters and relations to the surrounding formations as it occurs both in Antrim and Down†.

Trachyte Porphyry of Antrim.—The principal mass forms a group of eminences about four miles to the north of the town of Antrim, called Tardree Mountain, Carnearny Hill (1043 ft.), Brown Dod Hill, and Scolboa Hill. The tops of three of these hills are formed of basalt in beds capping the trachytic rocks; and it is supposed that basaltic sheets enclose the whole of the trachytic district, though the survey of the district being incomplete, the actual limits have not been determined in every direction.

The mineral constitution of the trachyte is generally uniform, although the relative proportions of the individual minerals occasionally vary. In general the rock consists of a nearly white or grey felspathic base, with individual crystals of sanidine and a triclinic felspar, blebs or grains of smoke-quartz, and rarely a little mica. In some places the grains of silica are exceedingly abundant, giving the rock the appearance of rhyolite or perlite, as described by L. von Cotta. Minute crystalline grains of magnetite appear in a sliced section. It is in this state that

* Geol. Trans. 1st ser. vol. iii. p. 189. See also Note to Hall's 'Ireland,' vol. iii.

† The trachyte porphyry of co. Down, near Hillsborough, is described in the Descriptive Memoir of the Geological Survey to accompany Sheet 36.

part of the iron stated in the analysis below probably occurs, though a portion is distinctly oxidized.

The rock is quarried as a building stone at Tardree Mountain, where it sometimes assumes a columnar structure. A specimen from one of the quarries was subjected to an elaborate analysis by Mr. E. T. Hardman, of the Geological Survey of Ireland, who gives the following as the constituents*:—

Analysis of Trachyte Porphyry—Tardree Quarry.

	per cent.
Silica	76·960
Alumina	5·101
Peroxide of Iron	2·344
Lime	7·064
Magnesia	0·295
Potash	4·262
Soda	1·818
Loss by ignition	2·102
Phosphoric Acid	trace
	99·943

Specific gravity.................. 2·433

Relations of the Trachytic and Basaltic Rocks.—During a recent visit the author ascertained with the greatest certainty the relative position of the trachytic to the basaltic rocks of the district. In the first place, there does not appear to be any passage of the two classes of volcanic rock into each other; and each having been erupted and spread out in sheets, exhibits a laminated or bedded structure, which enables the observer to determine their relative positions without much difficulty. Both at Carnearny and Tardree Hills the trachyte porphyry may be observed to dip beneath the basaltic rocks of the surrounding country; and the observations made here and elsewhere tended to show that of the two kinds of rock the trachytes are the older.

On the other hand, both at Carnearny Hill and Scolboa, the trachyte seems to have been penetrated by "necks" of later date filled with basalt, through which some portions of the overlying basaltic sheets may have been erupted. We are not, however, as yet in a position to say whether or not the trachyte is the oldest and lowest of all the tertiary volcanic rocks of county Antrim, as its base is nowhere exposed†.

The events which have taken place in the volcanic history of this locality appear to have been as follows:—

At some early stage of the Miocene period large masses of trachytic rocks were poured forth from one or more vents, doubtless accompanied by craters as in Auvergne. After probably a long interval of repose, new eruptions of basalt and dolerite took place through fissures and small volcanic vents breaking through the trachyte. These later eruptions of basalt may have enveloped the whole of the trachytic masses, which have been subsequently laid bare by denudation. The denudation of this region has been very great during Postpliocene and later times; and to it is due the obliteration of the actual craters of eruption over the whole volcanic region of Antrim.

Trachyte Porphyry of co. Down.—This rock is very similar in appearance and constitution to that of Antrim, consisting of a greyish felsitic base with crystals of sanidine and blebs of quartz. It is only visible at Ballyknock, about four miles west of Hillsborough, surrounded on all sides by Lower Silurian rocks, but not very far distant from the margin of the basaltic plateau of Antrim. There can be little

* Journ. Roy. Geol. Soc. Ireland, vol. iii. part 1, p. 27 (new ser.).

† Mr. Hardman considers that the amount of lime shown by the analysis proves that the trachyte has undergone some amount of metamorphosis or alteration, and considers it probable that it is consequently older than the basalt of Antrim, a view which subsequent examination in the field has enabled me to verify. Dr. Bryce thinks the trachyte occupies the position of the great ochre-beds.

doubt that it is of the same age as the trachyte porphyry of Antrim, both being referable, in all probability, to the great volcanic outbursts of the Miocene period.

Considerable uncertainty exists regarding the relations of the Downshire trachyte to the volcanic rocks of the adjoining country. It only appears in two or three spots within a small area; but the probabilities are that it is a portion of an old neck from which trachytic lava was erupted contemporaneously with that of Antrim. The higher portion of the mass, as well as the original vent, have been removed by denudation, and the district has since been deeply buried beneath Boulder-clay *.

On the Raised Beach of the North-east of Ireland. By Professor EDWARD HULL, *F.R.S., F.G.S., Director of the Geological Survey of Ireland.*

All along the eastern coast of Ireland, from Dublin Bay northward, there are to be found at intervals distinct evidences that the coast has been raised in recent times. These evidences are divisible into two kinds:—First, the occurrence of a narrow fringe of varying elevation, forming a terrace extending for some distance inland from the coast, and composed of stratified sand and gravel containing marine shells belonging to species now inhabiting the Irish Sea; and, secondly, the existence of old sea-worn cliffs forming the inland margin of these terraces, which are now beyond the reach of the highest tides. In the north of Ireland these cliffs are penetrated by caves which have yielded bones of animals, some of which are extinct in that part of the country, while the gravels of the old beach contain amongst the sea-shells worked flints in considerable quantity in county Antrim, which prove the elevation of the coast to have taken place since the human period.

The occurrence of the caves near the Giant's Causeway and the island of Rathlin was long ago noticed by Dr. Bryce and Mr. Andrews †, while the existence of flint-implements of human workmanship in the coast gravel of Larne and Belfast Lough was first brought into notice by the late Mr. G. V. Du Noyer ‡; but, as far as the author had ascertained, no one has treated these littoral phenomena as a whole, or shown that they belong to one period of general elevation along the whole coast-line, and that they are represented by similar phenomena on the coast of Scotland and the north of England.

Localities.—Commencing from the southward, the raised beach may be observed in several places around Dublin Bay, as along the coast of Ireland's Eye, forming a well-marked terrace; below Lowther Lodge, near Balbriggan, and in several places south of the mouth of the Boyne, the elevation of the terrace varies from 6 to 8 feet above high-water mark.

Along the Downshire coast the gravelly terrace may frequently be observed, as at Cloughy in the Ards, and along the coast at Killough and Ardglass to the southern shores of Belfast Lough. Along this portion of the coast the maximum elevation is about 12 feet, as determined by Mr. Traill and the author §. On the north side of the Lough, and around the shores of Larne and Island Magee, the gravel-beach with shells may be observed at Rhanbuoy, near Carrickfergus, where its elevation is 12 feet—at Kilroot, at Larne Harbour, and the eastern shore of Island Magee, with shells and worked flints—and at numerous points along the Antrim coast, such as the entrance to Glenariff, Red Bay, Ballycastle Bay, and Rathlin Island, where we have examples of old caves, sea-stacks, and shell-gravels reaching to an elevation of 20 feet above high-water mark.

It is in consequence of this gradually increasing elevation that the evidence of the rising of the coast becomes more striking northward; and from the above data it will be seen that the maximum elevation ranges from about 6 feet in Dublin Bay to 20 feet at the extreme north-eastern point of the Irish coast; so that by an easy transition the elevation falls in with that of the "25-feet beach," first described by Mr. Smith, of Jordan Hill, Mr. Maclarin, and more recently by Professor Geikie ||.

* Messrs. E. Hull and J. L. Warren, Explanatory Memoir to Sheet 36 of the Geological Survey of Ireland (1871).

† Brit. Assoc. Rep. 1834, pp. 658 & 660. ‡ Journ. Geol. Soc. London, vols. xxiv. & xxv.

§ Explanatory Memoir of the Geological Survey of Ireland, Sheets 49 & 50, p. 60.

|| Scenery and Geology of Scotland.

Similar phenomena are observable along the western shores of the British coast. Along the shores, bays, and headlands of Argyleshire and Ayrshire we find the fringe of shelly gravel, the old coast cliff, with caves and sea-stacks now high and dry, at an elevation nearly corresponding with that of the caves, shelly sands, &c. of the Antrim coast. Southward, towards the shores of the Solway Firth, the elevation decreases, and this decrease continues till the evidences of a raised beach almost disappear towards the estuary of the Mersey.

The identity, therefore, of the phenomena on both shores is evident, and is a matter of some interest in the physical geology of these islands.

Elevation of the Coast since the human period.—Another feature of identity of the beaches on both sides of the channel is the occurrence of works of human art imbedded in undisturbed strata along with marine shells. Mr. Geikie mentions that thirty canoes have been dug out of the 25-feet terrace along the estuary of the Clyde. Along the Irish coast the abundance of worked flints testify, as Mr. Du Noyer has shown, to the presence of man along these shores when they were to a greater degree than at present under water. These flints have also been observed in the gravels of the coast of Downshire, as well as in spots in the interior, and at a considerable elevation above the sea, imbedded in the soil.

Shells of the Raised Beach.—The shells which occur in this gravel are generally blanched and fragmentary, but are all of species at present existing in the adjoining sea. The following are the names of some at three different localities, in the identification of which the author has been assisted by Mr. W. H. Baily, F.G.S.

	Balbriggan.	Kilroot.	Larne.
Anomia ephippium	—	*	*
Cardium edule	*	*	*
—— echinatum	*	—	—
Dentalium entale	*	—	—
Mya arenaria	*	—	—
Pecten maximus	*	—	—
Buccinum undatum	—	*	*
Cerithium reticulatum	—	*	*
Nassa reticulata	—	*	*
Patella vulgata	*	*	*
Litorina litorea	*	*	*
—— litoralis	—	*	*
Fusus antiquus	—	—	*
Purpurea lapillus	*	—	—
Rissoa membranacea	—	—	*
Trochus umbilicatus	*	*	*
Turritella communis?	*	—	—
Turbo cinereus	*	—	—

Along the shores of Belfast Lough the raised gravel-beach rests on a blue clay of estuarine origin, containing a large number of genera and species of shells, of which Mr. J. Grainger has named eighty species*, to which Mr. S. A. Stewart has added others†. Some of these species have disappeared from the Lough, and others are exceedingly rare. When this estuarine mud was deposited the waters must have extended considerably beyond their limits, even at the time of the formation of the "20-feet" gravel-beach. The author suggested that this estuarine mud may represent the earlier period of submergence—marked in the west of Scotland by the "40-feet" water-line, of which traces have been noticed by Scottish geologists‡.

* Trans. Brit. Assoc. 1852, p. 43.

† List of Fossils of the Estuarine Clays of Down and Antrim, 1871.

‡ Archibald Geikie, 'Scenery and Geology of Scotland.'

A few Remarks on Submarine Explorations, with reference to M. Delesse's work entitled "Lithologie du fond des Mers." *By* J. Gwyn Jeffreys, *F.R.S.*

The lithology of the sea-bottom is not only a vast subject in its various relations to natural history and physical science, but is especially interesting in a geological point of view, because every part of our globe has been at one time or another covered by the sea. Mr. Jeffreys contended that it is almost impossible to ascertain, with any degree of certainty, what stratified formations are marine unless we find in them such remains of marine animals as were capable of being preserved. Exceptions doubtless occur, *e. g.* where the stratum had been subject to the action of carbonic acid, produced by the subsequent passage of rain or fresh water; in which case all calcareous organisms might have been dissolved before they became silicified or petrified. He then gave a short account of submarine explorations from the time when O. F. Muller first used a dredge for scientific purposes (about 1772) to the present day; and he summarized the results of the expeditions conducted by his colleagues and himself on board H.M.S. 'Porcupine,' under the auspices of the Royal Society in 1869 and 1870. But next to nothing is known of the enormous tracts of sea-bed which underlie the depths of the ocean in both hemispheres. He attributed the diffusion and geographical distribution of the marine Invertebrate fauna to the action of currents, and not to voluntary migration.

M. Delesse's work was recently published at Paris, and consists of two octavo volumes, besides an atlas of charts and maps. The precise date of publication does not appear; the dedication is dated 1st December, 1871. It forms part of a series called 'Publications scientifiques industrielles,' and purports to have been edited with the sanction of the Minister of Marine and Minister of Public Works.

While giving M. Delesse full credit for the laborious and conscientious manner in which he has evidently performed his great task, Mr. Jeffreys regretted that he had omitted to notice the reports on deep-sea explorations published by the Royal Society in 1869 and 1870, or the address of Mr. Prestwich (the late President of the Geological Society), which was published in May 1871, and particularly treated of those Reports. M. Delesse is a foreign member of the Geological Society. By consulting what had been published on the subject, M. Delesse would have been able not only to give fuller information, but to correct errors which unavoidably occur in an extensive compilation. For instance, his map of France during the Tertiary epoch does not show the communication which has been proved by naturalists and geologists to have then existed between the Bay of Biscay and the Gulf of Lyons. According to M. Delesse, there has been no communication since the Liassic period between the Atlantic and the Mediterranean north of the Pyrenees. His division of the French marine fauna into three provinces (Celtic, Lusitanian, and Mediterranean) does not agree with modern observations. Zoophagous mollusca do not, as stated by him, live on those which are phytophagous; pebbles ("galets") are not everywhere unfavourable to mollusca, even on coasts exposed to a stormy sea; and Foraminifera never crawl at the bottom of the sea. But it is to be hoped that these omissions and errors will be rectified in another edition of a work so desirable and important to scientific inquirers.

Note on the Discovery of Cretaceous Rocks in the Islands of Mull and Inch Kenneth. *By* J. W. Judd, *F.G.S.*

(Communicated by T. M'K. Hughes, F.G.S.)

Mr. Judd, after pointing out that the probable further extension of the chalk over a large part of Scotland had been inferred by the Duke of Argyll and Mr. Jamieson from the occurrence of chalk flints associated with Tertiary volcanic deposits, announced that he had now discovered, in the Western Islands of Mull and Inch Kenneth, fossiliferous beds of Cretaceous age.

On the Geological Distribution of Goître in England. *By* G. A. Lebour, *F.G.S.*

Notice of Veins or Fissures in the Keuper, filled with Rhætic bone-bed, at Goldcliffe in Monmouthshire. By J. E. Lee, *F.G.S.*

The alluvial plain stretching along the south of Monmouthshire, on the banks of the Bristol Channel, is broken in one or two places by liassic outliers, one of which forms the rising ground of Goldcliffe. The upper part of this outlier consists of Lower Lias and of the "*Ammonites-planorbis* beds." The strata immediately below are concealed by a high sea-wall, built on the Keuper Marls, which form a scar at low water. On this scar are many serpentine projections of various lengths and sizes. Some of them are 21 feet long, and a foot or even 18 inches wide. In some cases one appears to run under the other, and many of them are rounded, both above and below; not caused by the action of the present sea, but having been originally of this form, for these rounded portions are covered by the original Keuper Marl. They all consist of liassic bone-bed, with scales of *Gyrolepis* and teeth of *Hybodus* and *Saurichthys*. It is presumed that these projections are the casts in the bone-bed of fissures made in the Keuper before the bone-bed was deposited, which would then immediately fill them. The roundness of many of these projections is endeavoured to be accounted for by supposing these fissures to have been formed, either wholly or partially, as in the present day on clay-scars, by rills of running water on the marls previously to the deposit of the bone-bed.

On the Occurrence of Copper- and Lead-ores in the Bunter Conglomerates of Cannock Chase. By William Molyneux, *F.G.S.*

The author first stated that the district known as Cannock Chase was at the present moment the scene of a series of extensive mining-operations, which, if even moderately successful, would open up a very considerable area of valuable coal-seams, computed at not less than 200,000,000 tons, and push outwards a distance of upwards of five miles the northern apex of the South-Staffordshire coal-field. This apex, as is well known, rested on Brereton, where the Coal-measures are thrown down on the east by a fault of considerable range and influence, and on the west they are overlapped uncomformably by Bunter conglomerates. From Brereton the conglomerates continue northward over the Chase, which extends to within about four miles of the town of Stafford, up to which point the mining investigations alluded to will be carried.

The Cannock Mineral Railway from Cannock to Rugeley occupies a valley which runs nearly north and south, and unquestionably marks a line of fault of considerable importance. This fault is laid down in the maps of the Geological Survey, and has long been held as determining the western boundary-line of the workable coal-seams of South Staffordshire. West of this valley, from a point a little south of the town of Cannock, as far as Brocton and Milford, ranges the old surface-area of a large portion of Cannock Chase, the greater part of which is at the present time in a state of nature. In the maps of the Geological Survey, this area, with but a trifling exception, is laid down as Bunter pebble-beds, overspread by unconsolidated conglomerates of the New Red Sandstone; and it was in these beds, at a place called Shore Hill, about a mile north of the town of Cannock, that the author first detected, about two years ago, the copper- and lead-ore to which the paper referred. The conglomerates are here exposed by a section of from 80 to 100 feet, and they dip to the west at an angle of about 20°. They consist of the ordinary groups of pebbles and irregular intersections of sandy rock; and at about the middle of the section occurs the copper-ore in the form of a green carbonate, intermixed with the paste or cementing material in which the pebbles are set. The ore does not occupy any definite position in the gravels, nor is it confined to any particular horizon. It is sometimes met with in little holes left by the decomposition of Carboniferous limestone or chert-pebbles: it frequently coats and even occasionally insinuates itself into the interior of minutely fractured pebbles, and in places occurs in quantities which, if proportionately persistent, would be of great commercial value. At this pit the copper-ores, so far as the author had found, were not directly associated with lead; but about 20 feet beneath the copper-bearing beds, the latter

ore is found to occur in a series of thin cementing lines in the gravels, and following the natural inclination of the beds. In one instance the gravels are set in a light grey and greenish-yellow cement, in which occur traces of lead, iron, and aluminium soluble in acids. It is therefore to these conditions, namely the admixture of copper- and lead-ores with the Huntington gravels, that they owe their peculiar character as detrimental to the growth of weeds, and from which, but previously unknown, circumstance they have a large demand as material for the formation and repair of private roads and walks, the gravel having been sent so far as Ireland for this purpose.

During the early part of the present year the Fair Oak Colliery Company commenced sinking a pair of shafts for coal 4 miles to the north-east of the Huntington gravel-pits, about 2½ miles north of the West Cannock Colliery, half a mile west of the assured boundary fault, and about 2 miles west of the Brereton Collieries. The sinkings commence in drift sands and gravel, and are succeeded by Bunter conglomerates. At a depth of 29 feet from the surface lead-ore occurs in large quantities, disseminated freely amongst the gravels, which are coarse, and set in an excessively hard calcareous cement. The ore is, however, by no means continuous or persistent in its occurrence, but is found at irregular intervals in larger or smaller quantities, mixed up both with fine and coarse gravel, downwards to a depth of 85 feet from the surface. At 75 feet in the shaft copper-ore first shows itself, and is in this case distinctly separated from the lead. In passing further downwards, however, both these ores are found freely associated together and in large quantities; but the former, so far by no means reaches the percentage of the Huntington specimens. In this particular instance (that is, the association of the two ores) the Fair-Oak ores differ from those of Huntington, although it is of course quite probable that this may not be so in ground at present unexplored. The Fair-Oak ore consists of a green carbonate, occasionally passing into malachite, or carbonate and hydrate of copper; and there are also in some specimens traces of oxide of copper. The lead, which individually is more abundant than at Huntington, occurs in the form of ordinary galena or sulphide of lead; but so far no other ores, except manganese and iron, have been detected, although it is most probable that both cobalt and nickel, and possibly tin, may exist in small quantities.

With regard to the origin of these ores, or under what condition they were produced, the author would not venture an opinion; but he believed that they would be found to determine the lines of some important disturbance. Their occurrence at these particular and widely separated points was certainly curious and worthy of investigation. How far they extended downwards in the gravels would be ascertained by the sinkings, but they had not hitherto been met with below 108 feet from the surface. The author concluded by observing that he believed this was the only known instance of the occurrence of copper- and lead-ores in undoubted Bunter conglomerates in England.

On the Presence of Naked Echinodermata (Holothuria) *in the Inferior Oolite and Lias. By* C. Moore, *F.G.S.*

The Holothuridæ are a group of animals allied to the Echinodermata, but are destitute of shelly coverings. But sixteen recent British species are known, and in size vary, according to their genera, from 2 inches to 12 inches in length; the latter belong to the Cucumariæ, which on being brought up by the dredge have a marked resemblance to a disagreeable-looking, thick-skinned, slimy cucumber, many of the genera (of which there are but six British) being very rare. One of the rarer of these is the *Synapta*, which has imbedded in its skin a number of very minute spines in the form of anchors, by means of which, when touched, it adheres closely to the fingers. A Greenland species, allied to *Chirodota*, has its skin furnished with exceedingly minute wheels, which are known by being very pretty microscopic objects. Soft-bodied animals have almost entirely disappeared in a fossil state; but through the discovery by the author of the wheel-plates alluded to, he is able to establish the presence of at least four species of *Holothuria* in the

Lias and Oolite—one being from the Inferior Oolite, one from the Upper Lias, and two from the Middle Lias. The little wheel-like plates, which are about the fortieth of an inch in diameter, belong to *Chirodota*, and present considerable variety in form, some of them indicating structure not hitherto seen in recent species. They are formed of a number of minute wheel-spokes, varying from five to thirteen, which start from a central axis and are surrounded on the outside by a wheel-tire; on the inner edge of some species are a series of very minute teeth extending over the central cavity. One of the prettiest forms is from the Inferior Oolite, which the author did himself the honour to name *Chirodota Carpenteri*, after the President of the Association, who had done so much for microscopic science. In this species the wheel-tire was divided into a number of sections, giving it a very ornate appearance. The author concluded by expressing a hope that this interesting class of animals would receive a more systematic study than had hitherto been given to them.

On the Geology of the Thunder Bay and Shabendowan Mining-Districts, on the North Shore of Lake Superior. By H. ALLEYNE NICHOLSON, *M.D., D.Sc., F.R.S.E., F.G.S., Professor of Natural History in University College, Toronto.*

In this communication the author gave a short account of the leading geological features of the mining-districts of Thunder Bay and Lake Shabendowan, on the north shore of Lake Superior. After giving an account of the chief points of interest in the physical structure of Thunder Bay, it was shown that the chief metalliferous veins of this region are situated in the group of rocks which are known to Canadian geologists as the "Lower Copper-bearing series." The lithological characters of this series were briefly described, and it was shown that the age of the group is probably Lower Silurian. Finally, the author described the leading lodes of the district, and pointed out that it was likely to become one of the richest silver-bearing regions in the North-American continent.

The Lake Superior gold-districts are situated round Lake Shabendowan and to the N.E. of this, and occupy a large area of country which is placed about sixty miles from Thunder Bay, and is reached by the "Red River route." The geology of the country intervening between Thunder Bay and Lake Shabendowan was briefly described; and it was shown that the auriferous veins intersect a vast series of Huronian slates. These slates are for the most part greenish grey in colour, sometimes fine-grained, sometimes brecciated, and often glossy and soapy from the presence in them of talc. The slates are interstratified with beds of trap; and the author drew especial attention to the exceedingly close resemblance which they present to the so-called "Green Slates and Porphyries" of the Lake-district of the North of England—a resemblance which is shown, not only in the mineral nature of the rocks, but in the kind of scenery produced by their weathering. The author also expressed his opinion that these Huronian slates, though generally spoken of simply as "talcose slates," are truly of the nature of bedded felspathic ashes, and that the talc which they contain is a secondary product developed in them by metamorphic action subsequent to their original formation. The gold-bearing veins, finally, were shown to have generally an E. and W. or E.N.E. and W.S.W. direction, conforming to the strike of the rocks which they traverse; and the ores which they contain were shown to be chiefly auriferous copper-pyrites and free gold, with the occasional occurrence of galena, silver-glance, metallic silver, and iron-pyrites.

On Ortonia, *a new Genus of Fossil Tubicolar Annelides, with Notes on the Genus* Tentaculites. *By* H. ALLEYNE NICHOLSON, *M.D., D.Sc., F.R.S.E., Professor of Natural History in University College, Toronto.*

Having carefully examined numerous examples of the genus *Tentaculites*, Schlot., the author had arrived at the opinion that fossils of very different zoological affini-

ties had been included under this head. The genus *Tentaculites* is truly referable to the Pteropoda, and therefore all the forms which belong here must necessarily be free and unattached to foreign objects, since an attached or parasitic Pteropod is not conceivable. Similarly all the forms of *Tentaculites* proper must possess a straight shell, since the shell of the Pteropods is always either straight or regularly curved. No irregularly twisted and contorted tubes can, therefore, be properly referred to *Tentaculites*.

In accordance with these principles, the author formerly established the genus *Conchicolites*, to include Tubicolar Annelides the tubes of which are attached socially in clustered masses to dead shells (American Journ. of Science and Arts, vol. iii. No. 15, 1872). The author now proposed a second genus, under the name of *Ortonia*, after its discoverer, Mr. Edward Orton, of Ohio, to include certain other Tubicolar Annelides which had been previously referred to *Tentaculites*. The genus *Ortonia* comprises the single species *O. conica*, which is doubtfully identified with the *Tentaculites flexuosa* of Hall. The only known species is from the Lower Silurian (Caradoc) of North America, occurring in the rocks of the "Cincinnati Group" (Hudson-River series) of Ohio. The following diagnosis gives the characters of the genus and species:—

ORTONIA, Nich. Animal solitary, inhabiting a calcareous tube, which is attached along the whole of one side to some foreign body. Tube slightly flexuous, conical, in section cylindrical or subtriangular. Walls of the tube thick, cellular along the margin opposite to the attached surface, and markedly annulated by transverse ridges or rings along the sides.

Ortonia conica, Nich. Tubes growing attached to the shell of some mollusk; varying in length from $\frac{1}{4}$ to $\frac{1}{2}$ an inch, with a diameter of about $\frac{1}{10}$ of an inch at the mouth. Lateral annulations of the tube varying in number from 30 to 35 in the space of an inch. Surface smooth and completely destitute, so far as observed, of longitudinal striæ.

Notes on Machairodus latidens *found by the* Rev. J. MacEnery *in Kent's Cavern, Torquay. By* W. PENGELLY, *F.R.S., F.G.S.*

In this communication the author discussed the following questions:—

1st. Did Mr. MacEnery find more than five canines of *Machairodus latidens* in the Cavern?

2nd. Did he find there more than one incisor of this species?

3rd. To what era did the Kent's Hole *Machairodus* belong?

1. Having pointed out that in his "Cavern Researches" MacEnery mentioned no more than five canines, all of which had been traced, and explained that it had been inferred from certain expressions in documents preserved by the Yorkshire Philosophical Society that a sixth canine, found in the Cavern, had been presented by MacEnery to the Museum in the Jardin des Plantes, Paris, the author stated that he of *Machairodus*, whence it has been inferred that two incisors were found by had recently visited the Museum for the purpose of investigating the question, and had found that plaster casts of a canine, and not an actual tooth, had formed part of MacEnery's present to Cuvier.

2. Proceeding to the second question, he called attention to a plate, in Indian ink, the property formerly of Mr. MacEnery, but now of the Torquay Natural-History Society. It contains five figures, three of them representing two incisors MacEnery. In reply, it was pointed out that MacEnery mentions but *one* incisor, that there was no evidence that the figures represented Kent's Cavern specimens, that the plate certainly did not belong to the Cavern series, and was never referred to in MacEnery's manuscripts.

3. On the third and most important question (the era of the Cavern *Machairodus*) it was shown, from MacEnery's statements, that the canines and incisor were found in a branch of Kent's Hole known as the Wolf's Cave, mixed with remains of the ordinary cave mammals (Rhinoceros, Elephant, Horse, Ox, Elk, Deer, Hyæna, Bear, Wolf, and Fox)—that though of delicate structure, they, unlike some of the specimens found with them, bore no indications of contusion or abrasion—and

that their fangs had been gnawed. To this it had been objected that the Cavern contained two ossiferous deposits—one, termed "Breccia," found only in certain branches, the other, known as "Cave-earth," much more widely spread and of less antiquity—that fragments of the former were in certain localities found incorporated in the latter—that in all probability fossils had been occasionally washed out of the Breccia and redeposited in the Cave-earth—and that the following was the problem to be solved:—Was not this the history of the remains of *Machairodus* found in Kent's Hole? In reply, the author stated that whilst the Breccia teemed with fossils, they were the remains of bears only, that they were in a different mineral condition from those found in the Cave-earth, and that the teeth of *Machairodus* were in this respect identical with the latter—that whilst the fangs of the *Machairodus*-teeth were certainly gnawed, there were in the Breccia no indications of the hyæna, to which the work was no doubt to be ascribed (none of his teeth, or his coprolites, or bones gnawed by him); but in the Cave-earth his remains were more abundant than those of any other animal—that in the Wolf's Cave there were no traces of the Breccia, either *in situ*, or in incorporated fragments—and that the absence of marks of contusion or abrasion was incompatible with the hypothesis of dislodgement and re-deposition.

The paper concluded with the following expression of opinion on the three questions discussed:—

1st. There is no reason for believing or suspecting that more than five canines were found by Mr. MacEnery.

2nd. The evidence that more than one incisor was found by Mr. MacEnery is not conclusive.

3rd. *Machairodus latidens* belonged to the era of the Cave-earth of Kent's Cavern. There is at present no evidence that it belonged to the earlier period represented by the "Breccia;" and should such evidence present itself hereafter, it will simply prove that, like *Ursus spelæus*, *Machairodus* belonged to both eras.

P.S. Since this paper was written, a fine incisor of *Machairodus latidens* has been found in Kent's Cavern, by the Committee appointed by the British Association to explore the Cavern. It lay with the left lower jaw of bear in the uppermost foot-level of the Cave-earth, and had teeth of hyæna, bear, and horse vertically below it, thus confirming the conclusion already arrived at respecting its era.

On a remarkable Block of Lava ejected by Vesuvius at the Great Eruption, April 1872, *which proves the formation of Silicates through Sublimation. By* Herr G. vom Rath, *Bonn.*

The aggregates rich in minerals found in the strata of tuff on Monte di Somma are known to all mineralogists. Most of these magnificent mineral aggregates are no longer ejected by the volcano of to-day; but even now fragments of ancient lava are to be found amongst the projectiles of the volcano, distinguished by larger crystals of leucite than those in the more recent lava-streams and in the scoriæ.

It is of high geological interest to examine such evidence as may allow of newly formed minerals being recognized. Thus the ordinary lava, with its manifold mixtures of minerals and the delicate crystals in its cavities, cannot be the product of a simple cooling. Some of the crystals found in the lava were already in existence previously and were swimming in the stream, while some were crystallizing out of the fiery mass during the progress of its solidification; and, lastly, certain crystals appearing in cavities indicate the cooperation of vapour which had been active in the igneous magma. The distinction of the various formations of minerals is exceedingly difficult in the ordinary lava and scoriæ, as in the flowing and cooling lava different mineralogical processes may combine. A more favourable condition for observation is presented when a mass of ancient lava has been subjected again to volcanic activity, and has served partly as a substratum, partly as the base for new mineralogical formations. It is easier by far to distinguish such newly formed crystals accurately from the original lava in the blocks ejected than in the ordinary lava.

The study of such matters is conducting us to the view that the quantities of

water, hydrochloric acid, sulphuric acid, &c. exhaled by the craters and by the streams of lava are not only an accompanying phenomenon in the production of volcanic rocks and mineral aggregates, but that they are essentially cooperating agents in their origination. If once we succeed in proving and explaining the origin of minerals through vapours, or by cooperation of vapours, then will the key to many a problem relating to the plutonic rocks and their mineral veins be found.

A block of lava ejected by Vesuvius in its last eruption is very instructive, as throwing light on the formation of minerals by volcanic vapours. This block shows that in its interior small and fine crystals of pyroxene, mica, sodalite, hæmatite (specular iron), and magnetite were formed, whilst at the same time in the peripheric zone the pyroxene was melting and the leucite being destroyed by the volcanic heat.

Originally our block of lava had doubtless the appearance of so many varieties of lava from the dykes of the Somma. The character of the "lava antica" is well known to those acquainted with Vesuvius. The original nature of our rock is indicated by thickly agglomerated leucite of sizes up to 3 millims. (scarce), green pyroxene as large as 5 millims., and a magma with a great many cavities. Our fragment shows the constitution of the outside as well as of the interior. It is enclosed in a covering of black lava a few millims. thick, which is full of bladders on the surface, towards the interior dense and melted like obsidian. In this crust it is clear that some parts of the ancient lava, for instance the pyroxene, were melted with the new lava, in the midst of which our block was floating in the depths of the crater before the eruption. Though in the peripheric zone there is nothing to be seen of pyroxene, the leucite-crystals have been destroyed, but not melted; they rise out of the black scoriaceous matter as white grains soaked through, as it were, by the grey melted mass. To this external zone another succeeds, 10-15 millims. in thickness, in which the rock is firm and compact, and nothing is to be seen of new mineral formations. At this zone the pyroxene-crystals are likewise melted, and the cavities of the rock are filled with the melted mass penetrating from the outside. How could the hæmatite have been formed so as to escape being fused down with the igneous silicate? At a distance of 12-15 millims. from the periphery the pyroxene is not melted, at least not totally, to glassy drops; and it is here that, naturally without distinct limits, the inner part of the block commences in which the new formations have taken place. The cavities here are not filled with a melted mass, but covered with small delicate crystals that sparkle brightly and are in marked contrast with the dense melted magma of the peripheric zone. The sparkling covering of the little geodes consists principally of hæmatite and reddish-yellow pyroxene. In some cavities the sparkling is due to plates of hæmatite, in others nearly entirely to reddish-yellow pyroxene. Most of them show both minerals together and in intimate mixture. Both minerals, hæmatite and pyroxene, appear not only in the cavities, but also in the smallest fissures and holes of the general mass, and even of the leucite. Studied by a lens, the rock is seen everywhere to exhibit minute shining points of black hæmatite and red pyroxene. The little pyroxene-crystals, appearing here as new formations, resemble in colour and habit exactly those crystals which seven years ago I found implanted on the volcanic hæmatite of the spent fumarole in a scoriaceous hill near our lake of Laach, and which I announced as the first decided proof of a silicate originated by sublimation. Magnetite in small quantities, but in the same circumstances as pyroxene, is also found in our rock. By close observation of the little cavities one may also observe a fourth mineral in white crystals of pearly lustre, formed likewise by sublimation. It was somewhat difficult to determine that mineral; it has, however, been done with great certainty: it is sodalite.

The formation of hæmatite by volcanic sublimation, formerly a riddle, is now quite understood; but the chemical process, how silicates are formed by sublimation, is not as clearly understood even now. Chemistry will succeed in explaining this geological fact, as it has done with the volcanic hæmatite.

Even now we can settle with precision that water and chloride of sodium effect principally the origin of silicates by sublimation, as is the case with the volcanic hæmatite. Certainly it is not accidentally that we find sodalite, the silicate most

rich in sodium, to be sublimated by volcanic processes. The chloride of sodium derived from the sea is separated by the chemical actions of the volcano. Chlorine unites with hydrogen, iron, &c.; sodium plays its part in the formation of sodalite. Sea-water is the great source of volcanic phenomena, as well in the mechanical as in the chemical point of view. Steam raises the melted matter upwards to the border of the crater; steam and sodium operating on the lava originate new minerals. So sublimations will solve many problems in regard to new and ancient mineral formations, not to be explained either by supposing a merely aqueous process, nor by crystallization out of a molten fluid.

Twenty years ago Prof. Scacchi of Naples did suggest the sublimation of silicates at Vesuvius, without producing sufficient proofs to secure belief in this seemingly incredible fact. The pyroxenes implanted on the volcanic hæmatite in the neighbourhood of our lake of Laach, and the matter ejected by Vesuvius during the last eruption, place this remarkable fact beyond doubt.

On the Coal- and Iron-Mines of the Arigna District of the Connaught Coal-measures, Ireland. By T. A. Readwin, *F.G.S.**

The author first gave a sketch of previous writings upon this district, and acknowledged his indebtedness to the Geological Survey of Ireland for assistance in his researches.

The shales overlying the Upper Limestones of the district were surmised by the author to belong to the Yoredale series. Over these there are grits and shales, with three seams of coal, which the author referred to the Gannister series, remarking that a bed of true "gannister" occurred there.

The coal-field was divided into three districts by the author, each of which was separately described. He noticed at some length the clay, ironstone bands, and nodules, which occur over a much larger area than do the coals. The ironstone is richer and purer than most of the English clay-ironstone.

The coals contained an average of 77 per cent. of carbon, and the limestone an average of 40 per cent. of metallic iron.

The author believed that the time had come for a vigorous and scientific exploration of the district, which he felt convinced would soon become, as Sir R. Kane had long ago predicted, "an important centre of industry for the interior of the country."

On the Occurrence of a British Fossil Zeuglodon *at Barton, Hants.* By H. G. Seeley, *F.G.S.*

On certain Quartz-Nodules occurring in the Crystalline Schists near Killin, Perthshire. By Robert Sim, *M.D.*

On the Sub-Wealden Exploration. By W. Topley, *F.G.S.*

The author stated that this paper was submitted to the Section with the view of giving some information as to an experiment just being commenced to explore, by boring, the rocks underlying the Weald of Sussex, especially to reach and ascertain the nature of the palæozoic rocks. This undertaking has been planned by Mr. Henry Willett, in honour of the visit of the Association to Brighton.

The author first described the general structure of the Weald, illustrating his remarks by reference to the rocks exposed along the London and Brighton Railway. The lines of disturbance traversing this area were also described; and particular reference was made to the lowest known beds of the district (the Ashburnham beds), which are brought up to view by the main anticlinal on the north of Brightling. The ascertained thickness of these Ashburnham beds was stated to be about 350 feet, and the lowest known beds were shown to lie close to the surface in Rounden Wood, near Brightling.

The author then passed on to describe the range of the older rocks, with their associated Coal-measures, from the south of Ireland, through the west of England, and then again in Belgium. Following the reasoning of Mr. Godwin-Austen, as laid before the Geological Society in 1855, the author showed that a ridge of palæozoic rocks must extend under the south-east of England, and that such had been certainly reached at Harwich, possibly also at Kentish Town. The likelihood of the occurrence of Coal-measures along this line was also discussed.

It was shown that in the Boulonnais the Carboniferous Limestone, where last seen, is dipping south; and that in the Pays de Bray, near Gournay, Carboniferous Limestone has been found at a depth of only 22 metres below Kimmeridge clay. From these facts it seems extremely likely that a trough of Coal-measures may lie between these two points; and if so, this trough will probably be continued westwards under the Weald. But of this, and even of the character of the Coal-measures if found, there must necessarily be great uncertainty. The sub-Wealden boring may not at once determine these points, but it will give important data towards the future determination of them. With regard to the thickness of the rocks to be passed through, nothing certain could be said. The author, as the result of a careful examination of the evidence, concluded that 1600 feet would probably be the maximum depth to the palæozoic rocks. Mr. Prestwich, as the result of other inquiries, had suggested 1700 feet as the maximum depth. These results, independently arrived at, gave great hopes that the numbers named would not be exceeded. The minimum depth could scarcely be less than 600 or 700 feet.

With regard to the site selected for the boring, it was shown that it was on the line of the main anticlinal, and within about 100 feet of the lowest known part of the Ashburnham beds, and consequently in a most favourable spot for this experiment.

On the Geology of Moab. *By the* Rev. Canon Tristram, *LL.D., F.R.S.*

In this paper it was shortly stated that the valley of the Jordan coincides with a synclinal line. On the western side of the Dead Sea there are only three springs, and here there are vast banks of marl heaped against the cliffs. On the east side there is but little marl; the cliffs are formed of New Red Sandstone, and where the Eocene limestone rests upon this, there are numerous springs. The basalt of the district is modern, as the lava-streams overlie the Tertiary limestones. No craters were observed in this district, and the origin of the lava is at present unknown. To the north-east of the Dead Sea there is a fertile plain of New Red Sandstone, backed on the east by a range of limestone hills (Tertiary); beyond this there is a region as yet wholly unexplored, which was reported to be a vast volcanic tract covered with ruined cities.

On the Formation and Stratification of Sedimentary Rocks.
By T. Ogier Ward, *M.D. Oxon.*

On Slickensides, or Rubbed, Polished, or Striated Rocks.
By T. Ogier Ward, *M.D. Oxon.*

BIOLOGY.

Address by Sir John Lubbock, *Bart., M.P., F.R.S., Vice-Chancellor of the University of London, President of the Section.*

Adverting to the introduction of natural science into our great public schools Sir J. Lubbock was glad to say that the regulations which are being drawn up under the Public Schools Act by the new governing bodies generally contain a provision that natural science shall be taught to all boys in their passage through the

schools. He hoped that this provision would be fairly carried out, and that a due proportion of time, of the scholarships, and of the exhibitions would be devoted to natural science. It was only fair to say, with regard to private schools, that they had little choice of action until the universities and great schools led the way. A deputation of the Council had waited on Mr. Forster, to urge the importance of the introduction of natural science into the elementary schools also of the country. The Government had distinctly abandoned the principle that primary education should be confined to reading, writing, and arithmetic; but little had been effected as yet for the practical introduction of scientific instruction. The experience of Dean Dawes and Prof. Henslow had conclusively shown the aptitude of the children for such instruction; and he rejoiced to see that the School Boards of London and Liverpool had determined on the introduction of elementary science into all schools under their control. If it was objected that this could only amount to a smattering, it might well be asked, who has more? Those who are most advanced in knowledge know best how slight this knowledge is. Indeed every fresh observation opens up new lines of inquiry. Every biologist would admit the impulse to research which had been given by the publication of Mr. Darwin's 'Origin of Species.' Yet it was surprising how much fundamental misapprehension still surrounds Mr. Darwin's views. Thus Browning, in one of his most recent poems, said :—

> That mass man sprung from was a jelly lump
> Once on a time; he kept an after course
> Through fish and insect, reptile, bird, or beast,
> Till he attained to be an ape at last,
> Or last but one.

It was hardly necessary to point out that Mr. Darwin would be the first to repudiate such a theory. These types of structure might be derived from one origin; they were certainly not links in one sequence. It was one thing to recognize in natural selection a *vera causa*; it was another to assume that all animals were descended from *one* primordial source. As to the first alternative, he could not himself feel any doubt; and whatever conclusion might be come to as to the latter, the publication of the 'Origin of Species' would not the less have constituted an epoch in biology. How far the present condition of living beings was due to natural selection,—how far, on the other hand, the action of natural selection has been modified or checked by other natural laws, by the unalterability of types, by atavism, &c.,—how many types originally came into being, whether they had arisen simultaneously or successively,—these and many other similar questions remained to be solved, even if we admitted the theory of natural selection. All this, indeed, had been clearly pointed out by Mr. Darwin himself, and would not have needed repetition but for the careless criticism by which, in too many cases, the true question had been obscured. Without, however, discussing the argument for and against Mr. Darwin's conclusion, we so often meet with travesties of it like that which he had quoted, that it might be worth while to consider the stages through which some one group (say that of insects) had come to be what they were, assuming them to have developed from simpler organisms under the influence of natural laws. The question was one of great difficulty. It was hardly necessary to say that they cannot have passed through all the forms of animal life, and the true line of development would not be agreed upon by all naturalists. Almost every one would, however, admit that embryology and development were our best guides. The various groups of Crustacea, for instance, however different the mature conditions, were for the most part very similar when they quitted the egg.

So, again, in the case of insects; the differences between the different groups of insects were indeed great. The stag-beetle, the dragonfly, the moth, the bee, the ant, the gnat, the grasshopper; these, and other less familiar types, seemed at first to have little indeed in common. They differed in size, in form, in colour, in habits, and modes of life; yet, following the clue of the illustrious Savigny, it had been shown, not only that they were constructed on one common plan, but that other groups, such as Crustacea and Arachnida, could be shown to be fundamentally

similar. If we compared the larvæ, this fact became much more evident. It had been pointed out by Brauer and also by himself that the two types of larvæ which Packard had proposed to call the eruciform and leptiform ran through the principal groups of insects. This was obviously a fact of great importance. If individual beetles were derived from a form very similar to that of the existing genus *Campodea*, it was surely no rash hypothesis to suggest that the Coleoptera as a group might be so. If he were asked to describe the insect type, he would say it was an animal composed of head with mouth-parts, eyes, and antennæ, a thorax made up of three segments, each with a pair of legs, and a many-segmented abdomen with anal appendages. This, for instance, would describe the larva of a small beetle named *Sitaris*; and, speaking generally, it might be said that (excepting the weevils) Coleoptera generally were derived from larvæ of this type. The same was also true of Neuroptera, Orthoptera, and Trichoptera. The larvæ of Lepidoptera, from the large size of the abdomen, had been generally, and, as he thought, wrongly, classed with the maggots of flies, bees, &c. The three thoracic segments were, on the contrary, marked by legs, and, excepting greater clumsiness in general appearance, they essentially agreed with the type already described. No Dipterous larvæ belonged, however, to this type. Insects, then, widely different in their mature state closely agreed in their larval states. Was there any mature form which also corresponded to the hexapod larvæ of insects? We need not have been surprised if this type, through which it would appear that insects must have passed so many ages since (for winged Neuroptera have been found in carboniferous strata), had long ago become extinct. But the genus *Campodea* still represented it. It seemed to him also highly significant that its mouth-parts were intermediate between the haustellate and mandibulate types. There were good grounds, therefore, for considering the various types of insects to have descended from ancestors more or less resembling the genus *Campodea*.

This ancient type may have been possibly derived from one less highly developed, resembling the modern Tardigrades, such as *Macrobiotus*. Further still, such genera as *Lindia* closely resembled the vermiform type of larva general in Diptera and occurring in other groups. There was reason to think that amongst insects the segments preceded the appendages in appearance, which was the reverse of what was the case in Crustacea, although this stage of development might have eluded observation from its transitoriness. Fritz Muller and others considered the vermiform type of larva more recent than the hexapod. Considering, however, that the vermiform type was altogether lower in organization and less differentiated than the *Campodea* (hexapod) form, he considered that the latter was derived from vermiform ancestors; and Nicolas Wagner had shown, in the case of a small gnat allied to *Cecidomyia*, that these vermiform larvæ still, in some cases, retain reproductive powers. Such a larva very closely resembled some of the Rotatoria, such as *Lindia*, in which both cilia and legs were altogether absent. He agreed with Herbert Spencer in regarding this vermiform type as the result of a modified segmentation. For the next descending stage we must look amongst the Infusoria. Other forms of Rotatoria, such as the very remarkable *Pedalion* discovered last year by Mr. Hudson, seemed to lead to Crustacea through the *Nauplius* form. (The true worms appeared to constitute a separate branch of the animal kingdom.)

Probably, again, in some such forms as Hackel's *Magosphæra* and *Protamœba*, the primitive ancestors of even such lowly organized types as *Macrobiotus* and *Lindia* must be looked for. And if it were said to be incredible that even the lapse of geological time should have been sufficient to bridge over the immense interval between such creatures as these and *Campodea*, or even the Tardigrades, we might consider what happened under our eyes in the development of each one of these creatures in the proverbially short space of an insect's individual life. The development of the egg of a Tardigrade went through the same course as the *Magosphæra*; and from the cells which were the result of the process of yolk-segmentation, the body of the Tardigrade was built up. Similar processes occurred in the development of many other species belonging to most distinct groups. Yolk-segmentation occurred in Entozoa, in Rotifera, Echinodermata, Mollusca, and Vertebrata, as was illustrated by the diagrams which were shown. It was true that yolk-segmentation was not universal in the animal; kingdom but its absence

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Probably, again, in some such forms as Hackel's *Magosphæra* and *Protamœba*, the primitive ancestors of even such lowly organized types as *Macrobiotus* and *Lindia* must be looked for. And if it were said to be incredible that even the lapse of geological time should have been sufficient to bridge over the immense interval between such creatures as these and *Campodea*, or even the Tardigrades, we might consider what happened under our eyes in the development of each one of these creatures in the proverbially short space of an insect's individual life. The development of the egg of a Tardigrade went through the same course as the *Magosphæra*; and from the cells which were the result of the process of yolk-segmentation, the body of the Tardigrade was built up. Similar processes occurred in the development of many other species belonging to most distinct groups. Yolk-segmentation occurred in Entozoa, in Rotifera, Echinodermata, Mollusca, and Vertebrata, as was illustrated by the diagrams which were shown. It was true that yolk-segmentation was not universal in the animal; kingdom but its absence

might be attributed to that suppression of stages of embryological development which might be illustrated from many cases both in zoology and in botany.

Of course it might be argued that these facts have not really the significance which to him they seemed to possess. It might be said that when the Divine power created insects they were created with these remarkable developmental processes. So it had been said that when God created the rocks he created the fossils in them. Probably no one would now maintain such a theory; and he believed the time would come when the contents of the egg and its developmental changes would be held to teach as truly the course of organic development in ancient times as the contents of the rocks told us the past history of the earth itself.

In conclusion, there was one matter which he could not but touch upon, but which he yet could not properly treat at length. Great anxiety had been felt during the last few months lest changes should be made at Kew which would prove prejudicial to its scientific work, and lead to the retirement of Dr. Hooker. He felt sure that he only expressed the feeling of the scientific world when he said that such an event would be a misfortune to science, and when he stated his hope that the Government would do nothing to retard or impede the valuable scientific work now going on at Kew.

BOTANY.

On Traquairia, *a Radiolarian Rhizopod from the Coal-measures. By* W. CARRUTHERS, *F.R.S.*

In the investigation of a large series of sections of fossil plants, prepared by Mr. Norman, Mr. Carruthers had detected several spherical spiniferous bodies not unlike *Xanthidia*, but having a very different structure and a much greater size. The hollow globular cavity is included in a clearly defined structure, which Mr. Carruthers thinks is a fenestrated shell; but he had not been able to secure sections which completely established this point. Beyond this there is a considerable thickness of a spongy substance which rises externally into numerous cones, the bases of which are in close proximity. From the apex of each cone there proceeds a hollow echinate spine. The echinations are also hollow; and at the apparent base of the spine these echinations are produced into hollow tubes, which, repeatedly branching and anastomosing and increasing in number downwards, enclose the radial hollow spine in the mass. The whole arrangement of the parts agreed with what is found in some existing forms of Radiolarians, especially in some with solid spines; but the hollow structure of these organs in the fossil indicated relations with a small section of the recent group. No certain indication had yet been detected of the central capsule; but Mr. Carruthers having found starch and other readily perishable substances perfectly preserved in some fossils, had hopes that the central capsule may have left traces behind in some specimens. Rhizopods of the Radiolarian type, but without the central capsule, had been described by Cienkowski, and especially by Archer. Perhaps amongst them this palæozoic form may at last be placed. One would expect it to be a freshwater organism; yet it might, as a marine animal, indicate the first trace of one of the changes of level which were not unfrequent in the Carboniferous period. Mr. Carruthers had associated with this interesting animal the name of his friend Prof. Traquair, of Dublin, to whom he was indebted for assistance in working out its structure. He proposed to name it *Traquairia*.

Ramie, a new Textile Plant; with Description of its Uses, Mode of Propagation, Cultivation, as practised in the Southern United States of America. By C. F. DENNET.

This new textile, lately introduced to agriculturists of the Southern States of America, is a native of the island of Java, and was first brought to Europe for

investigation in 1844, when it received the botanical name of *Bœhmeria tenacissima*, and, from the beauty and strength of its fibre, obtained much attention in manufacturing circles. Since that time every encouragement has been given to producers in the East Indies to induce them to cultivate it in sufficient quantity to supply the demand; the result is that a considerable quantity is annually received in Europe and manufactured into fabrics of the finest quality, excelling linen of the finest texture in strength, beauty, and finish, and rivalling even silk in lustre.

The author then described the advantages of Ramie over cotton and other staples now cultivated in the Southern United States. He stated that the fibre, when prepared for the spinner, is beautifully white, soft, and glossy, closely resembling floss silk in appearance—that it is stronger than the best flax, and readily receives the most difficult dyes without injury to its strength or lustre.

A detailed account was also given of the mode of propagating and harvesting the plant.

On the Cones of Pinus pinaster. *By* Prof. Dickson.

The author called attention to a series of cones of *Pinus pinaster*, exhibiting transitions from one spiral system to another by what has been called "convergence of secondary spirals." Such transitions, he pointed out, were due to the fusion of two consecutive scales in some one of the secondary spirals. This fusion of two scales does not produce any disturbance in the set of secondary spirals in which it occurs, but causes a definite diminution in the number of all the other sets of secondary spirals. The undisturbed set of secondary spirals, as running continuously through the two systems, Prof. Dickson terms "constants." That the above explanation of the phenomenon of convergence is really correct he holds to be virtually proved:—1st, by the fact that in a good many cases a distinctly double scale, formed by coalescence of the two, actually occurs at the point of convergence; 2nd, that all gradations of fusion from a distinctly double to apparently single scale occur; and, 3rd, that in *all* cases of transition by convergence, whether with or without a distinctly double scale, the resulting spiral is invariably identical with that which, if the system of the lower spiral and the number of the constants be given, would theoretically result from fusion of the consecutive scales in one of the constants.

On Stigmariæ *from the Fossiliferous Strata at Auchentorlie.* *By* Prof. Dickson.

The author exhibited a number of large *Stigmariæ* obtained by him from the fossiliferous strata intercalated between beds of various traps (Porphyrite, Greenstone, &c.) at Auchentorlie, near Bowling, on the river Clyde. These appeared for the most part to occur in mudstone, which doubtless represents the soil in which these rhizomes were imbedded. The fossils in question had their structure beautifully preserved by infiltration with calcium carbonate. Besides plant-remains in the mudstones, shales, and impure coal of this locality, there occur in the shales (as has been pointed out by Mr. John Young of Glasgow) the teeth and scales of Lower-Carboniferous fishes referable to the genera *Palæoniscus* and *Amblypterus*.

On Phylloxera vastatrix. *By* Prof. Thiselton-Dyer, *B.A.*, *B.Sc.*

The author gave a brief account of the ravages which this insect is producing in the vineyards of Europe, entailing, in many cases, their complete destruction. From a recent dispatch to the Foreign Office it appeared that the *Phylloxera* had now reached Portugal—one vineyard producing an average quantity of 60 pipes produced only two, owing to its effects. It was not too much to say that one of the most important cultures in Europe was seriously menaced. The *Phylloxera* was of North-American origin. It was a conspicuous instance of the well-known fact that organisms which in their native homes were kept in check by the stress of competition, increased in an altogether disproportionate rate when trans-

ported to new situations where the struggle was absent. The Rev. M. J. Berkeley believed that he had lately ascertained the connexion of a hitherto mysterious disease of the roots of peach-trees with an insect very similar to the *Phylloxera*.

On the Flora of Moab. By A. W. Hayne, *M.A.*

The 250 plants found in Moab from the beginning of February to the middle of March belong to 58 natural orders, of which by far the best represented are:—Leguminosæ with 35 species, Compositæ and Cruciferæ each with 26, and Graminaceæ 23. The remainder belonged to Liliaceæ, Scrophulariaceæ, Labiatæ, Boraginaceæ, Umbelliferæ, &c. From the great abundance of springs, the eastern shore of the Dead Sea is comparatively fertile. The most conspicuous difference which results is the abundance of the date-palm, of which, on the west, only a single clump survives near Jericho.

Summary Analysis of the Flora of Sussex (Phænogams and Ferns). By W. B. Hemsley.

The total number of indigenous species (after Babington's 'Manual') is about 1000. This number would be reduced by about 100 if we take Hooker's 'Student's Flora' for our authority on species.

To the above number we may add 59 fully established introduced species, bringing the total up to 1059.

Separating this number into the three primary divisions, we have:—

Dicotyledons	776 species, or	73·28 per cent.
Monocotyledons	250 ,,	23·61 ,,
Acotyledons	33 ,,	3·11 ,,
	1059	100·00
Herbaceous species	937 ,,	88·47 per cent.
Woody species	122 ,,	11·53 ,,
	1059	100·00
Perennial species	767 ,,	72·42 per cent.
Annual or biennial species	292 ,,	27·58 ,,
	1059	100·00

A few of the more interesting features of the Flora are:—number of species to area (1461 square miles), species peculiar to certain formations, maritime species, and rare species, especially those of the "Atlantic" and "Scottish" types.

Maritime and salt-marsh species	76
Peculiar to the chalk	56
Essentially bog-plants	36
Aquatic and marsh-plants	213

Amongst rare water- and marsh-plants may be mentioned:—*Isnardia palustris*, *Limnanthemum nymphæoides*, *Scirpus carinatus*, *S. triqueter*, and *Potamogeton acutifolius*.

Belonging to the "Scottish" type of Watson:—**Pyrola media*, **Habenaria albida*, and **Festuca sylvatica*, with several others, all very rare and local.

Cicendia filiformis, **Sibthorpia europæa*, **Vicia lutea*, *Bartsia viscosa*, **Genista pilosa*, and *Melittis Melissophyllum* may be noted as south-western types extending to Sussex.

Alchemilla vulgaris and *Carex montana* are interesting on account of their distribution.

A prominent feature of the Wealden flora is the extent of heath land and the great size the heath attains.

The apparent absence of *Hypericum montanum, Saxifraga granulata, Chrysosplenium alternifolium, Pyrola minor, Pinguicula vulgaris,* and about 50 other species found in adjoining counties is noteworthy.

The species peculiar to the county are *Phyteuma spicatum, Lonicera xylosteum,* and *Trifolium stellatum,* neither of which, however, is admitted, without question, as being indigenous, though there can be little doubt of the first. The second, Babington says, is indigenous, and the last is generally considered a ballast introduction, but it has held its ground for upwards of half a century.

[Species preceded by an asterisk are not found in the adjoining counties.]

On some Specimens of Tortula inclinata. *By* Prof. Lawson.

The author said that Prof. Lindberg, while staying at Oxford, was good enough to go through his collections of Mosses and correct all those that were wrongly named. Amongst other mistakes, Prof. Lindberg detected this species, which was new to the British Isles, mixed up with specimens of *Tortula tortuosa.* This specimen, Prof. Lawson explained, had been gathered by himself two years ago, growing on the sides of the rocks in the old stone-pits at Holton, about four miles from Oxford, and had been confounded by him with *T. tortuosa.* He briefly described the points in which these two very closely allied species differed, and expressed an opinion, founded upon its geographical distribution, that now the attention of bryologists was called especially to it, it would be found elsewhere in Britain.

On a curious Elm. By M. Moggridge.

This was an elm growing in Kensington Gardens, near the Engine House at the head of the Serpentine. Its height was 55 feet and circumference 7 inches. At the height of about 8 feet from the ground, above a decayed portion of the trunk, a mass of aërial roots descended to the ground without further contact with the trunk.

Zoology.

On the Structure and Development of Mitraria. *By* Prof. Allman, *F.R.S.*

Several specimens of the remarkable larval form, to which Johann Muller gave the name of *Mitraria,* were obtained by Prof. Allman in the Gulf of Spezzia, and were made the subject of careful study of structure and development. Mecznikoff had recently examined another species of the same form; and the author was enabled to confirm the main result arrived at by him, that *Mitraria* was the larval form of an annelid. In some fundamental points, however, regarding the process of development, his observations did not agree with those of the Russian zoologist; while in structure there are some important features which have not been described by either Muller or Mecznikoff—differences which may, in some cases at least, depend on actual differences between the species examined.

The nervous system is well developed, and consists in the principal central portion of a large quadrilateral ganglion, formed by the union of two lateral ones, and situated on the summit of the transparent dome-like body of which the larva mainly consists. From this two very distinct chords are sent downwards, so as to form a pair of commissures with two small ganglia which are situated at the opposite side of the alimentary canal. Besides these, two other small ganglia exist in the walls of the dome at the oral side of the great apical ganglion, and two similar ones at the aboral side; these send off numerous filaments, which dive at once into the walls of the dome, while each sends off a long filament to the region where the alimentary canal begins to bend downwards towards its aboral termination. The great apical ganglion supports two sessile ocelli, with pigment and lens, and two small spherical vesicles, each containing a clear spherical corpuscle. These last the author regards as auditory capsules.

A system of vessels (probably water-vascular) was also described. This consists mainly of a sinus which surrounds the great apical ganglion, and sends off three branches, which run in a radial direction in the walls of the dome, two lateral and one aboral, and appear to open into a sinus which surrounds its base.

In the progress of development the aboral end of the alimentary canal becomes elongated in the direction of the axis of the dome, carrying with it the walls of the base of the dome, which are to form the proper body-walls of the future worm; and in this way a long cylindrical appendage becomes developed, and hangs from the central point of the base. At first there is no trace of segmentation; and this is subsequently induced on the cylindrical body of the worm by the formation of consecutive annular constructions.

The process of development, as observed by the author in the species of *Mitraria* examined by him, thus differs in several points from that observed by Mecznikoff. Among these the most important is that the ventral side of the worm is formed simultaneously with the dorsal instead of subsequently to it and independently of it, as in the case described by Mecznikoff The development of the worm was not traced to the ultimate disappearance of the dome-like body of the larva.

On some points in the Development of Vorticellidæ. *By* Prof. ALLMAN, *F.R.S.*

The author described, in a beautiful branched and clustered Vorticellidan, a process different from any which had been recorded by those observers who had described the so-called encysting process and the behaviour of the "nucleus" in the Vorticellidæ.

In almost every cluster some of the zooids composing it had become greatly altered in form; they had increased in size, and instead of the bell-shaped form of the others, had assumed a globular shape, and had lost both oral orifice and ciliary apparatus, while their supporting peduncle had ceased to be contractile. In the younger ones the contractile space of the unchanged zooid was still very evident, but was fixed, showing no tendency to alteration of size, and the so-called nucleus was very distinct and larger than in the ordinary zooids. The whole had become enveloped in a transparent gelatinous-looking investment.

In a slightly more advanced stage another envelope, in the form of a brown horny capsule, begins to be secreted between the proper wall of the zooid and the external gelatinous investment. It is at first thin and smooth, but it gradually acquires considerable thickness, and becomes raised on its outer surface into ridges enclosing hexagonal spaces.

In this stage the capsule has become too opaque to admit of a satisfactory view into its interior; but if the capsule be carefully opened, its contents may be liberated so as to render apparent their real nature. It will be then seen that these consist of a minutely granular semifluid plasma surrounding the "nucleus," which has much increased in size and occupies a large portion of the cavity of the capsule. The condition of the contractile space could not be determined; it has probably altogether disappeared.

In a further stage the "nucleus" has undergone an important change; for instead of the long cylindrical form it had hitherto presented, it has become irregularly branched, has acquired a softer consistence, and has, moreover, broken itself up into two or more pieces. This change in the "nucleus" is invariably accompanied by the appearance of nucleated cell-like bodies, which are scattered through the corpuscular plasma which had filled the rest of the capsule; they are of considerable size, of a spherical form, and with their nucleus occupying the greater part of their cavity, and having its nucleolus represented by a cluster of granules.

In other capsules, apparently the more advanced, no trace of the so-called nucleus of the vorticella-body could be detected; and it seems to be entirely replaced by the spherical nucleated cells, which had now still further increased in number. It is impossible not to regard these cells as the result of the disintegration of the "nucleus;" and the conclusion is a legitimate one that they are finally liberated by the natural dehiscence of the capsule, and become developed into new Vorticellidans.

On the Structure of Noctiluca. *By* Prof. ALLMAN, *F.R.S.*

The author gave an account of some researches he had made on *Noctiluca miliaris*. They were mostly confirmatory of the results arrived at by other observers, more especially by Krohn, Quatrefages, Busch, Huxley, and Webb, while they further served to supplement the observations of these zoologists.

At one end of the meridional depression is the vibratile flagellum with the mouth at its base; and here the depression becomes quite superficial, while the opposite end is much deeper, and is here abruptly terminated by a vertical wall. Just outside of this deep end of the depression there commences, by a funnel-shaped enlargement, a very slightly elevated ridge of a firmer consistence than the rest of the body; it terminates abruptly after running down, in a meridional direction, over about one third of the circumference of the body. The author had reason to believe that this ridge is traversed in its length by a canal which opens close to the aboral extremity of the meridional depression by a funnel-shaped orifice. The mouth leads into a short cylindrical gullet; and the author confirmed the existence of the vibratile cilium contained within the gullet, as originally described by Krohn, and of the ridge, with its projecting tooth, described by Huxley as existing in the gullet-walls. The floor of the gullet is formed by the central mass of protoplasm, here naked and in direct contact with the surrounding medium. The vibratile cilium springs from this floor; and near the root of the cilium is a depression in the floor, which can be followed for a little distance into the protoplasm.

Besides the well-known branching processes which radiate from the central mass of protoplasm to the walls of the body, there is also sent off from the central mass a broad, irregularly quadrangular process, which extends to the outer walls, where it becomes attached along the line of the superficial meridional ridge. The lower free edge of this broad process has the form of a thickened border, and at its upper edge it becomes continuous with a plate-like striated structure, which the author regarded as representing a duplicature of the body-walls.

In contact with the central protoplasm is the nucleus, a clear spherical body about $\frac{1}{2000}$ of an inch in diameter.

The body-walls are composed of two layers—an external thin, transparent, and structureless membrane, and an internal thin granular layer of protoplasm, which lines the structureless membrane throughout its whole extent, and which receives the extremities of the radiating processes from the central mass. Under the action of iodine solution and other reagents, the protoplasmic layer may be seen to detach itself from the outer structureless membrane, and, along with the radiating bands, contract towards the centre. It admits of an obvious comparison with the primordial utricle of the vegetable cell.

The flagellum, which is given off close to the margin of the mouth, is a flattened band-like organ, gradually narrowing towards its free extremity, and with its axis transversely striated like a voluntary muscular fibre throughout its whole length. It seems to have the power of elevating its edges, so as to render one of its surfaces concave, and thus becomes converted into a semitube, which may assist in the conveyance of nutriment towards the mouth.

The nucleus is a spherical vesicle, with clear colourless contents, among which minute transparent oval corpuscles may usually be detected. When acted on by acetic acid, the difference between the contents of the vesicle and its wall becomes very apparent; and the contents may now be seen accumulated towards the centre as a minutely granular mass, with some of the oval corpuscles entangled in it.

The radiating offsets, which extend from the central protoplasm to the peripheral layer, contain well-defined clear corpuscles, which slowly change their relative places, as if under the influence of very feeble currents. These offsets, indeed, closely resemble the radiating protoplasm-filaments which extend from the protoplasm surrounding the nucleus to the walls of the primordial utricle in the vegetable cell. The peripheral layer contains, scattered through it, numerous minute cell-like bodies: these are spherical and of various sizes; in the larger ones a distinct central nucleus may be detected.

It is scarcely correct to regard the central mass of protoplasm as a true stomach. The author had failed to find any evidence of a permanent gastric or somatic cavity; and he regarded the protoplasm mass to which the gullet leads as representing the "parenchyma" of the Infusoria, and, like this, allowing of the solid food being forced down into it from the gullet and there encysted in extemporaneously formed vacuolæ. The food also frequently forces its way from the central mass into the radiating processes; and diatoms and other microscopic organisms may be seen in these processes enclosed in cyst-like dilatations of them, extemporaneously formed for their reception at various distances from the central protoplasm.

It was considered probable that the canal which seems to exist in the superficial ridge affords exit for certain effete matters, which may be conveyed to it through the process by which it is kept in connexion with the central protoplasm.

Our knowledge of the phenomena of reproduction and development in *Noctiluca* is still very imperfect, and the author saw little which seemed capable of throwing additional light on this subject. He regarded it, however, as probable that the nucleated cell-like bodies which are present in the peripheral layer of protoplasm have a reproductive function, and are destined after liberation to become developed into new individuals.

From the account now given it will be apparent that *Noctiluca* consists essentially of an enormously vacuolated protoplasm, involving a nucleus and enclosed in a structureless sac, the vacuolation taking place to such an extent as to separate the contents into a peripheral layer of protoplasm which remains adherent to the outer sac, and into a central mass which is kept in communication with the peripheral layer by processes of protoplasm which pass from one to the other. The author believed that the nucleus of *Noctiluca* had a significance different from that of the so-called nucleus of the ordinary Infusoria, and that it admitted of a closer comparison with the true cell-nucleus. He was of opinion that the nearest ally of *Noctiluca* would be found in the somewhat anomalous infusorial genus *Peridinia*.

In conclusion the author detailed some observations he had made on the luminosity of *Noctiluca*; and he gave reasons for maintaining that the seat of the phosphorescence is entirely confined to the peripheral layer of protoplasm which lines the external structureless membrane.

On the Structure of Edwardsia. *By* Prof. ALLMAN, *F.R.S.*

The structure of this beautiful little Actinozoon differs in many important points from that of both the Zoantharian and Alcyonarian polypes. It was shown that just within the mouth the walls of the stomach-sac project into the cavity of the sac in such a way as to form eight complicated frill-like lobes—that the eight vertical radiating lamellæ which project into the body-cavity from the outer walls, and are composed of parallel longitudinal fibres enclosed between two membranous layers, do not reach the stomach-sac in any part of their course—and that eight strong muscular bundles pass symmetrically through the whole length of the body-cavity, being attached at one end to the disk which carries the tentacles, and at the other to the floor of the body-cavity, while they are free in their intervening course.

Attached along the length of about the posterior half of each muscular bundle is the long sinuous generative band, with its chord-like craspedum loaded with thread-cells. Just before terminating at the lower opening of the stomach-sac each of the eight generative bands enters a most remarkable pectinated organ, which appears to be quite unrepresented in any other group of the Cœlenterata. It was difficult to suggest the true significance of these organs; their relation to the generative bands might lead to the belief that they are testes, or they may be analogous to the so-called cement-glands which exist near the outlet of the oviducts in some of the lower animals. In this case they might supply some additional investment to the ova at the time of extrusion.

The author regarded *Edwardsia* as presenting a very distinct type of actinozoal structure, which occupies an intermediate position between that of the zoantharian and that of the alcyonarian polypes. He also compared it with the extinct rugose

corals of the palæozoic rocks, to which it corresponds in the numerical law of its body-segments, and of which it might, in some respects, be regarded as a living non-coraligenous representative.

On the Structure of Cyphonautes. *By* Prof. Allman, *F.R.S.*

This remarkable little organism, whose structure and ultimate destination have been variously described by different observers, was obtained by the author in considerable abundance in Moray Firth. The animal is enveloped in a mantle, and the whole enclosed in a delicate, transparent, structureless test formed by two valve-like triangular plates, which are in contact along two edges, and separated from one another by a narrow interval along the third. Its form is thus that of a very much compressed pyramid. The author distinguishes by the term base the broader edge where the two plates of the test are separated from one another, while the other two edges are distinguished as the anal and abanal edges. The apex is the angle opposite to the base; and here a narrow passage exists, through which the fleshy walls of the mantle are brought into immediate contact with the surrounding water.

In the base are two large oval openings, one (the larger) situated towards the anal edge, and the other towards the abanal. The former leads directly into the cavity of the mantle; its edges are prolonged by a hollow membranous lobe, ciliated on its margin, and uninterruptedly continued round the anal side of the opening, but deficient on the opposite side.

A large part of the mantle-cavity is occupied by the pharynx, a spacious thin-walled sac, which opens into the mantle-cavity by a long curved somewhat S-shaped slit with thickened and ciliated margins, which at one side are continued, in the form of two short ciliated tentacles, beyond the large opening situated near the anal side of the base. Towards the apex the pharynx becomes suddenly narrow, and is here lined by vibratile cilia, and marked by circular striæ which possibly indicate the presence of sphincter fibres. It now turns towards the anal side, and then bends downwards towards the base and enters a thick-walled subcylindrical stomach. This runs towards the base parallel to and a little within the anal edge of the test, and is ultimately continued into a short straight intestine, which terminates by an anal orifice in the mantle-cavity near the outer opening of the latter. From the upper part of the walls of the pharynx a narrow bundle of fibres passes to the apex of the mantle-cavity.

Upon each side of the pharynx, and lying against the stomach and intestine, is a large oval mass. Its situation would suggest the probability of its being an hepatic organ; but it is altogether so enigmatical that it would be rash, with our present knowledge of it, to insist on assigning to it any special significance.

In contact with each of these enigmatical organs is a small tubercle, from which a bundle of short fibres pass off in a radiating direction. The resemblance of these bodies to a pair of nervous ganglia is obvious; but the author was more inclined to regard them with Schneider as indicating points of attachment of the contained animal to the two valves of the test.

The smaller of the two openings in the base (that, namely, which is situated near the abanal edge of the animal) is, like the other, surrounded by a hollow membranous lobe with ciliated margin; this is uninterruptedly continued round the abanal side of the opening, but is deficient on the opposite side. The opening leads into a special chamber entirely shut off from the cavity of the mantle and from the pharynx. The walls of the chamber are lined with cilia, and it has within it, or in immediate connexion with its walls, two peculiar structures. One of these is a somewhat pyriform organ, which, with the narrow end close to the orifice of the chamber, extends from this point into its cavity; it is composed of a mass of spherical bodies. The other extends over the roof of the chamber in form of a cap: it consists of two portions, one of which lies directly on the walls of the roof and has a transversely laminated structure, which, however, disappears towards the abanal side of the chamber; the other is an oval mass of globular cell-like bodies, and lies on the free convex surface of the laminated portion.

Here, again, this part of the *Cyphonautes* is in the highest degree enigmatical;

and yet it is difficult not to believe that in the structures just described we have an ovary and testis with associated accessory structures.

The author observed no further fact which might tend to throw light on the ultimate destination of *Cyphonautes*, and more especially nothing which might tend to confirm the remarkable views lately published by Schneider, who believes that he has traced its development into the polyzoal *Membranipora pilosa*. The structure is considerably more complicated than Schneider seems to be aware of; while the opinion of this observer, that the whole of the proper *Cyphonautes* structure becomes absolutely obliterated, and the body of the animal converted into an amorphous mass of cells, from which the *Membranipora* becomes evolved, not by a process of budding, but by a differentiation of structure, is so startling, that, notwithstanding the partial assent lately given to it by Nitsche, we are compelled to wish for further confirmation of the evidently careful observations of the German zoologist.

If the abanal chamber described above with its associated structures really belongs to the generative system (and it is hard to say what else it can be), the view that *Cyphonautes* is a polyzoal larva is scarcely tenable.

Les Baleines du Crag d'Anvers. Par le Prof. P. J. Van Beneden, *LL.D.*

Les travaux exécutés pour les fortifications d'Anvers ont mis au jour une quantité innombrable d'ossements fossiles, provenant d'animaux marins, parmi lesquels les *Cétacés à fanons* ou les *Mysticètes* dominent complétement.

L'on sait que c'est sur une étendue de plusieurs lieux que l'on a fouillé le sol pendant des années et que ce sol est le plus riche ossuaire connu du monde entier. Cette abondance d'ossements entassés rappelle quelques localités où les débris de Cétacés vivants s'accumulent encore tous les jours. Il y en a sur les côtes d'Afrique; et non loin de la côte du Chili, la petite île de Mocha est si riche, sous ce rapport, dit un baleinier, que l'on pourrait en meubler tous les musées de l'Europe. C'est ce que l'on pourra faire également avec les ossements fossiles d'Anvers.

A côté de débris de Siréniens et de Tortues gigantesques, que l'on ne trouve plus que dans les régions tropicales, on y découvre des restes d'oiseaux qui visitent périodiquement les mêmes lieux; des Phoques comme les *Trichecodon*, qui ne vivent plus que dans les régions polaires, des Cétodontes sous la forme de Dauphins à long rostre, des Ziphioïdes de toutes les grandeurs et des Cétacés à fanons de toutes les dimensions. C'est de ces derniers que nous voulons parler dans ce moment.

Au-dessus d'une couche d'argile d'une grande puissance, que Dumont a appelée Rupélienne (Miocène), se trouvent des bancs de sable, noir d'abord, gris ensuite, jaune ou rouge après, dont le premier répond au Diestien de Dumont (Miocène), les deux autres à son Scaldisien, c'est-à-dire au Crag (Pliocène). Au-dessus de ces sables nous trouvons des couches quaternaires dans lesquelles on découvre assez abondamment des restes d'Eléphant, de Rhinocéros, d'Ours, d'Hyène, de Renne, d'Elan, et de Cerf ordinaire, etc. etc. Il est à remarquer que ce sont, à quelques exceptions près, tous animaux terrestres. Nous avons recueilli, même au milieu de ces débris d'animaux, un long couteau de silex à la profondeur des couches inférieures de la tourbe.

Le sable en dessous ne renferme que des débris d'animaux marins. Il correspond au Crag de Suffolk; mais, contrairement à ce qui se voit en Angleterre, ces ossements ne sont pas roulés et ils ne sont guère mêlés avec des débris d'animaux terrestres.

On voit que les cadavres ont été tranquillement enfouis sur les lieux, au fond d'un estuaire, tandis que les ossements trouvés en Angleterre ont évidemment été pendant longtemps le jouet des vagues.

C'est dans les couches inférieures, ou le sable noir, que l'on voit paraître, parmi les Cétacés, les Dauphins à long rostre, les *Eurinodelphis* de mon collègue du Bus, les superbes *Ziphioïdes* qu'il a fait connaître dans les Bulletins de l'Académie de Belgique, puis les Mysticètes, c'est-à-dire les Cétacés que l'on appelle communément Baleines. Mais presque toutes ces Baleines sont des animaux comparativement de

petite taille, qui rappellent la *Neobalæna marginata*, signalée par le Docteur Gray dans ces derniers temps, à lo'uest de la Nouvelle Zélande.

L'on peut dire, comme pour certains poissons fossiles, que des formes animales, fossiles aujourd'hui dans l'hémisphère boréal, sont conservées par quelques représentants dans l'hémisphère austral.

Ces baleines naines, de la fin de la période Miocène et du commencement de la période Pliocène, sont fort différentes entre elles et se rapportent respectivement aux types connus actuellement, c'est-à-dire aux *Balæna*, *Balenoptera*, et *Megaptera*. Il n'y a que les *Erpétocètes* qui s'éloignent de tous ceux que nous connaissons, par la singulière conformation de leur maxillaire inférieur. Le condyle articulaire au lieu de se trouver au bout, laisse derrière lui en dessous une longue apophyse.

Mais si ces cétacés représentent déjà nos types actuels, il est à remarquer que c'est par des espèces naines, et ceux qui atteignent la taille de nos baleines actuelles ne se trouvent que dans le Crag le plus récent.

C'est donc, contrairement à ce que nous montrent les animaux terrestres, pendant la période actuelle que les cétacés ont atteint leur plus grande dimension. Ne peut-on pas dire que c'est aussi dans le cours des dernières périodes géologiques, que les mers se sont le plus accrues et se sont le plus complétement séparées des continents? L'Atlantide à fait place à l'Atlantique, et de nouveaux cétacés ont pris des dimensions en rapport avec la nouvelle étendue de leur milieu.

La loi d'après laquelle les formes fossiles sont d'autant plus semblables aux vivantes qu'elles sont plus récentes, est parfaitement observée, absolument comme la loi d'après laquelle la taille des animaux correspond avec le continent ou le milieu qui les nourrit.

Les ossements les plus abondants à Anvers appartiennent aux *Balænopterides* plutôt qu'aux Balænides, mais ils forment des types auxquels il a fallu imposer des noms nouveaux. Quelques-uns de ces types sont connus, et il y en a que l'on a trouvé déjà dans une grande partie de l'Europe: en Portugal, en Lombardie, en Crimée, à Malte, en Autriche, en Allemagne, en Angleterre, dans les Pays-Bas et en Belgique on a trouvé des restes de *Cetotherium*.

On connait cependant aussi déjà quelques Balénides. M. Seeley a fait connaître depuis 1865, le *Palæocetus Sedgwickii*; et j'ai reçu récemment la nouvelle d'une tête de baleine naine trouvée au fond de la mer sur la côte du Danemark.

Nous ne vous fatiguerons pas en vous exposant les noms nouveaux que nous avons cru devoir proposer pour ces nouvelles formes. Ces noms se trouvent dans les Bulletins de l'Académie de Belgique du mois de Juillet dernier (" Les Baleines Fossiles d'Anvers"), mais je demanderai d'ajouter que le Musée Royal d'Histoire Naturelle de Bruxelles renferme les différents cétacés déterminés jusqu'à présent, et que, grâce au concours actif du Directeur, M. Dupont, tous ces objets sont aujourd'hui exposés au public. Il y en a parmi eux, comme les *Balænula* et les *Balænotus*, qui y sont représentés par des squelettes presque complets; tous les *Cetotherium* y figurent par des portions de crâne, des os de l'oreille, des os maxillaires et des colonnes vertébrales.

Cail's Lock Salmon-pass or Swimming-stair. *By* RICHARD CAIL.

After remarking upon the importance of the subject of salmon-passes, and the failure, more or less decided, which had hitherto attended experiments in erecting them, the author went on to describe his "*Lock-pass or Swimming-stair.*" It consists essentially of a series of troughs or locks arranged like the steps of a stair; they are kept constantly filled, and communicate with each other through submerged apertures.

The arrangement is such as to connect in a continuous chain of deep water, flowing at a moderate speed, the upper and lower levels of a stream or river, whether broken either naturally by a fall or artificially by a dam. The front of the pass is made high, so as to divert all flood-water from the dam or impounded water into the highest lock. The feed-aperture is situated considerably below the apex of the dam, and is larger than any of the other apertures which communicate between lock and lock; consequently all the locks become full of water, and the surplus overflows at the brim of each. The apertures which unite the locks are therefore all

submerged, and they constitute a continuous line of communication by water between the lower and upper stream, however great the difference in level may be, a higher fall merely requiring a greater number of locks than a lower. To moderate the velocity of the flow of water through the trough-aperture, the apertures are not placed in continuous line, but diagonally opposite, with small jetties. The difference in level between each lock will generally be about 15 inches, and the size of the locks 6 or 7 feet square; the area of the trough-apertures about 1 foot, that of the feed-apertures being about one fourth larger. When space is limited and the height to be surmounted considerable, the locks may be arranged like a winding or spiral stair. The plan of construction is not costly; generally it may be made of timber.

Mr. H. E. Dresser exhibited British Specimens of *Hypolais icterina*.

Sur les Dents du Macrauchenia *et leur Mode de Remplacement.* *Par* M. Paul Gervais.

Le Prof. Paul Gervais rappelle d'abord les caractères spéciaux de la faune quaternaire propre à l'Amérique méridionale, et les principaux travaux dont elle a été l'objet dans ces derniers temps. Le nouveau mémoire qu'il se propose de consacrer aux animaux propres à cette faune paraîtra parmi ceux de la Société Géologique de France, et comprendra des détails relatifs à plusieurs des espèces éteintes découvertes dans l'Amérique du sud, particulièrement au *Macrauchenia*.

M. Paul Gervais fait connaître en partie la première dentition de ce genre si curieux de mammifères, et il en décrit en même temps les dents de remplacement pour la mâchoire inférieure. Celles de ces dents qui répondent aux incisives, aux canines, et aux avant-molaires sont remarquables par la disposition festonnée de leur couronne, qui rappelle d'une manière inattendue la forme caractéristique de l'*Iguanodon*. M. P. Gervais présente une planche sur laquelle ces caractères sont représentés.

En ce qui concerne la classification du *Macrauchenia*, il pense, avec M. Owen, que cet animal doit être rapproché de Rhinocéros, et qu'il appartient à la même famille que ces derniers; ce qui lui paraît résulter de l'ensemble des caractères propres à ce genre qui répète dans la série de Jumentés, ou Anisodactyles, une condition comparable à celle des Anoplothériums parmi les Porcins, et fournit, parmi les Rhinocérides, l'exemple d'une formule dentaire ramenée à son expression typique.

Les nouvelles études de M. P. Gervais compléteront à certains égards les notions publiées par MM. R. Owen, Bravard, et Burmeister, ainsi que par lui-même, relativement à ce genre singulier de Mammifères. Les pièces qu'il a examinées font partie des acquisitions récemment accomplies par le Muséum de Paris.

Diversity of Evolution under one set of External Conditions. *By the* Rev. John T. Gulick.

Note on the employment of Yachts in Deep-sea Researches. *By* Capt. Marshall Hall, *F.G.S., F.C.S., &c.*

Having had some experience in dredging &c. from a yacht, and having met with sundry yacht-owners who would like to join in such pursuits, the author suggests that the British Association would be a proper body to form a Committee to encourage, organize, direct, and inform yachting naturalists with regard to the mode in which they could be of most use. He considers that though no single small vessel without steam and experienced men could investigate a locality thoroughly, yet, by an interchange of apparatus and a division of the work to be done (one yacht taking current observations and sounding, another the dredging, and so forth), a small squadron making a rendezvous, say, at some little-known West-India island or the Canaries, might accomplish very complete and interesting investigations, besides doing valuable work nearer home.

He suggests that a yacht of, say, 150 tons is the most practically useful size, not being too large to get under weigh quickly, and yet of sufficient size to carry stores, gear, a steam-launch, fuel, and engine, the last to be equally available for the launch-screw and a winch on the ship's deck.

But he also considers smaller craft to be equally useful in some ways.

The Committee might be empowered to communicate with the Royal Yacht Clubs and ask the support of naturalist members; they might also consider the advisability of voting grants for attaching "experts" to such squadrons to describe the more perishable animals &c. on the spot.

In conclusion the author points out the assistance to the supply of large aquaria which the development of tastes for dredging would be—yachts visiting fishing-stations and saving alive the prizes allowed by fishermen to be wasted, dredging with the yachts and boats themselves, making the nearest British port with a valuable cargo in portable tanks, and sending them alive to their inland or coast homes.

Mr. J. Wasdall, of Scarborough, considers that the education of a body of sailors to zoological work, the keeping of a list of them, so that yacht owners might know where to find such skilled hands, would be one of the valuable results of the labours of such a Committee. The interchange of expensive apparatus and gear would be another.

On the Mollusca of Europe compared with those of Eastern North America. By J. Gwyn Jeffreys, *F.R.S., F.G.S.*

The author had dredged last autumn on the coast of New England, in a steamer provided by the Government of the United States, and had inspected all the principal collections of Mollusca made in Eastern North America. The author compared the Mollusca of Europe with those of Massachusetts. He estimated the former to contain about 1000 species (viz. 200 land and freshwater, and 800 marine), and the latter to contain about 400 species (viz. 110 land and freshwater, and 290 marine); and he took Mr. Binney's edition of the late Prof. Gould's 'Report on the Mollusca of Massachusetts' as the standard of comparison. That work gives 407 species, of which the author considered 40 to be varieties, leaving 367 apparently distinct species. About 30 species may be added to this number in consequence of the recent researches of Prof. Verrill and Mr. Whiteaves on the coast of New England and in the Gulf of St. Lawrence. He identified 173 out of the 367 Massachusetts species as European, viz. land and freshwater 39 (out of 110), and marine 134 (out of 257), the proportion in the former case being 28 per cent., and in the latter 52 per cent.; and he produced tabulated lists of the species in support of his statement. He proposed to account for the distribution of the North-American Mollusca thus identified by showing that the land and freshwater species had probably migrated from Europe to Canada through Northern Asia, and that most of the marine species must have been transported by the Arctic current through Davis's Strait southward to Cape Cod, and the remainder by the Gulf-stream from the Mediterranean and western coasts of the Atlantic in a northerly direction.

On the Theory of the Scientific Value of Beauty in relation to the doctrines of Mr. Darwin and Mr. Galton. By F. T. Mott, *F.R.G.S.*

Preliminary Report on Dredgings in Lake Ontario. By H. Alleyne Nicholson, *M.D., D.Sc., M.A., F.R.S.E., Professor of Natural History in University College, Toronto.*

In this communication the author gave a short preliminary account of a series of dredgings carried out in June and July in Lake Ontario. This lake had not, up to this time, been explored by the dredge; and some valuable facts having been brought to light in Lake Superior in 1871, by systematic dredging, he was therefore induced to apply to the Government of the Province of Ontario for a grant of

money to be expended in dredging Lake Ontario. With a praiseworthy appreciation of the true value of such researches, the Government at once generously granted the necessary assistance. The dredgings were carried on partly in a yacht and partly in a steamer, and were prosecuted by hand, the apparatus employed being similar to that used in marine dredging, except that a bag of embroidery canvas was placed outside the ordinary net—an addition rendered necessary by the extremely fine nature of the mud at great depths. Upon the whole, the results obtained in Lake Ontario agreed very fairly with those obtained in Lake Superior, there being a general conformity in the phenomena observed. The fauna of Lake Superior, however, so far as deep water is concerned, is decidedly richer than that of Lake Ontario; whilst some of the more remarkable species discovered in the former appear to be absent in the latter. As might have been anticipated, the fauna of Lake Ontario is not extensive, though some forms occur in great profusion. The shallow-water fauna is very rich in individuals, and the number of species is quite considerable for fresh water. Beyond eight or ten fathoms the fauna becomes very scanty; and when depths of from twenty to fifty fathoms are reached the list becomes reduced to some Annelides and Amphipod Crustaceans. The nature of the bottom, also, at great depths is very unfavourable to life, consisting almost everywhere of a fine, unpalpable, greyish-blue clayey mud, the temperature of which is very low.

Out of thirty-one forms, in all, discovered by the author in Lake Ontario, the most interesting were the Annelides and Crustaceans. The Annelides were very abundant, and consist of species of *Nephelis* and *Clepsine*, *Sænuris* and *Chirodrillus*, some of the leeches presenting phenomena of especial interest. Of the *Crustacea*, the most important is a little Amphipod, which occurred in depths of from thirty to forty-five fathoms, and which the author identified with the *Pontoporeia affinis* of the Swedish lakes. This species and the Stomapod, *Mysis relicta*, are found in Lakes Wetter and Wener in Sweden; and it is well known that they have been believed, upon good grounds, to support the view that these lakes had been at one time connected with the sea. It is therefore a very interesting fact that these species should both have been detected in Lakes Michigan and Superior. The *Pontoporeia* the author had now detected in Lake Ontario; but it is a singular fact that the *Mysis* (which is common in Lake Superior) had not been found to occur at all in the dredgings carried on by the author.

How a National Natural-History Museum might be built and arranged with advantage. By R. A. Peacock, *C.E.*, *F.G.S.*

The museum now building at Kensington is about 800 feet long by 200 feet wide; its area, therefore, is about $3\frac{2}{3}$ acres, the market value of which is about £44,000. Its cost will be nearly £350,000. The circumference of the building is 2000 feet, which, multiplied by the three floors, gives a length of galleries of about 6000 feet*. A *complete* collection of whales and dolphins would fill all this and there would be no space for any other animals, much less for the botanical and other specimens. The known species of whales are thirty-two, of from 50 to 110 feet long, and seventy-two dolphins, from 12 to 25 feet; and the number of these Cetacea, Dr. Gray says, "will be very much extended." Taking the whales at the average moderate length of 60 feet and the dolphins at 15 feet, we have a total length of 3000 feet. But the writer believes a National Museum ought to contain a male skin and skeleton and a female skin and skeleton of every species of Vertebrata, and the young of the same, also a sectional drawing of each species, showing the skeleton within the skin. And Dr. Sclater is probably right in proposing that the young of all

* Since this paper was written, the author has seen a perspective view and ground-plan of the Government Museum, the building of which is let for £352,000. It averages 600 feet long by about 267 feet wide, and is four stories high including the basement, and affords about half the requisite space for a *complete* museum. The building as to its exterior will be very elegant. The view and plan are in 'The Builder' of January 4 and 11. The drawings of the building proposed by the author are at the Geological Society's Rooms.

ages, examples of variation, and preparations of the internal structure should also appear. It would therefore seem at first sight as if a length of at least 12,000 feet would be required; but this may be very much reduced. The spaces provided for the Cetacea in the sequel of this paper are 26 feet wide and from 20 down to 12 feet high; therefore all but the largest whales can be placed side by side, with their respective skeletons suspended over them, and the young, varieties, and preparations can be placed alongside without requiring additional lengths. But allowing for the numbers being "very much extended," the total length will certainly exceed a mile, and will therefore, as stated above, fill the museum now building. The number of volumes now in the British Museum Library exceeds a million, and is said to double itself in fifteen years. Thus in half a generation hence the books will have so much increased as not to leave room for either of the great collections, viz. (*a*) the Arts and Curiosities, and (*b*) the Natural History, which will also have increased; and especially so if the present unexhibited portions of the collections should be exhibited, as they ought to be. Dr. J. E. Gray says, in a letter to the present writer:—"The space proposed [at S. Kensington] is very small, not more than we have at present; and there is a great want of room for the unexhibited portion of the collection, not nearly as much as we have here" (Brit. Mus.). And he advocates the Arts and Curiosities being placed in the museum now building: and, in truth, that appears to be the judicious and inevitable conclusion, because it is simply impossible to build at S. Kensington one of the usual rectangular museums of only three (? four) stories, which shall hold all the specimens illustrating Zoology, Botany, Mineralogy, and Palæontology, without spreading it over some 8 or 9 acres (worth £100,000), and an unnecessarily vast space to walk over. It would cause sad confusion to fit up the present new building for Natural History, and afterwards to alter it for the reception of the Arts and Curiosities.

Proposed New Museum.—This will contain $2\frac{3}{8}$ miles nearly (in addition to the auxiliary Cetacea-room of 1356 feet) of spaces and glass cases, for the Vertebrata and fossils, and to be called the Animal Gallery. This gallery will also contain 880 window-cases covered with plate glass, each 6 feet long by 3 feet wide (*i e.* a mile long by a yard wide), the whole well lighted by 880 large non-transparent glass windows—mainly for the Invertebrata. For Plants, Lecture-rooms, and Library, an area of 57,000 superficial feet is provided ($=1\frac{1}{3}$ acre nearly), and for Mineralogy 50,000 superficial feet ($1\frac{1}{4}$ acre and more): these would be lighted by a circular non-transparent glass roof, 320 feet in diameter. All these spaces will be divided into a suitable number of separate rooms by non-transparent glass partitions, so that (for example) only one species of Cetacean can be seen by each person at once, to avoid confusion; and galleries would be provided at half the height for seeing closely all the very large specimens. The writer therefore proposes to take $3\frac{3}{4}$ acres at the angle formed by Prince Albert Road with Gore Road, and forming a square of 400 feet; of this area the angles would be occupied by various auxiliary offices, &c. The central circular museum would be carried up to the height of twelve stories or 120 feet, and would be 344 feet in diameter; and access could be gained up or down in a few seconds, to any floor, at a cost of a $\frac{1}{2}d.$, by means of an hydraulic hoist worked by a small steam-engine. The entrance would be by a porch 20 feet square, lighted by a glass roof, and containing in plate-glass cases busts in marble of the most eminent naturalists, dead and living. On entering the museum, to the right would be the Animal Gallery, which would form an inclined plane, rising 1 in 47, and afterwards 1 in 94, and the heights of gallery varying from 20 down to 9 feet. On the right as you ascend would be the windows and window-cases, and on the left spaces surrounded by brass railings for the *Cetacea*: next in order all the other living animals being Vertebrates; when they have all been placed, the extinct animals will succeed in plate-glass cases, behind which would be the work-rooms all the way to the top of the building. The order would be, first, the latest vertebrate fossils, then the other vertebrate fossils according to age, the oldest being at the top. Those who wished to see the fossils in the usual order would always have the option of ascending by the hoist to begin. The circular form has been chosen because a square of equal area would have a circumference of 136 feet greater length of wall and window, which, multiplied by the

height, 160 feet, gives an area of wall and window saved by the circle of 21,760 superficial feet. There would also be a saving in the distances to be walked over. The whole museum would be lightning-proof and also fire-proof, as no wood would be used. The building to be faced with vermilion-coloured bricks with stone dressings, the walls being strong and well bonded. A three-story museum of $3\frac{3}{8}$ acres costing £350,000, one of $8\frac{1}{4}$ acres would cost proportionably £795,000. The expense of the twelve-story museum and its appendages, worked out in detail at the prices current in April 1872, would be £354,788, which includes £6471 for kamptulicon floor-cloths, seats, tables, and desks; but it includes nothing for the $3\frac{3}{8}$ acres of land. This twelve-story museum could be built equally well on any other site where the square of 400 feet had two of its adjoining sides bounded by roads, if no other lofty buildings were erected too near it. [Messrs. Spon of Charing Cross have published the paper *in extenso.*]

On the Perforating Instruments of Pholas candida. *By* JOHN ROBERTSON.

On a new Rhinoceros, with Remarks on the Recent Species of this Genus and their Distribution. By P. L. SCLATER, *M.A., Ph.D., F.R.S., Secretary to the Zoological Society of London.*

On the 14th of February last the Zoological Society of London received in their Gardens a female two-horned Rhinoceros, which had been captured near Chittagong four years previously, and had been since kept in captivity at that station in India. This animal had been referred to *Rhinoceros sumatrensis* of Cuvier by the author and by other writers who had spoken of it, that being the only species of the Asiatic two-horned section of rhinoceroses hitherto recognized by naturalists.

The recent acquisition of a female of the veritable *R. sumatrensis* from Malacca had enabled the author to compare the two animals together, and had led him to the conclusion that the first-mentioned specimen belonged to a different species, which he proposed to call *Rhinoceros lasiotis*, or Hairy-eared Rhinoceros, its most obvious external peculiarity being the long hairs which fringe the ears.

The existing species of Rhinoceros certainly known were considered by the author to be six in number, viz.:—

a. Asiatici: dentes incisivi superiores duo.

a'. cornu nasali unico.

1. *R. unicornis*, Linn. Ex Assam.
2. *R. sondaicus*, Cuv. Ex Java, Borneo et penins. Malayana.

b'. cornibus duobus.

3. *R. sumatrensis*, Cuv. Ex Sumatra et penins. Malayana.
4. *R. lasiotis*, mihi. Ex Chittagong.

b. Africani: dentes incisivi nulli.

5. *R. bicornis*, Linn. Ex Afr. trop. merid. et or.
6. *R. simus*, Burch. Ex Afr. trop. merid.

Notice of an apparently new Marine Animal from the Northern Pacific. By P. L. SCLATER, *M.A., Ph.D., F.R.S., Secretary to the Zoological Society of London.*

The author exhibited specimens of bodies bearing the general external shape and appearance of long thin tapering white willow wands from 4 to 6 feet in length, which he had received from Captain David Herd, of the Hudson's Bay Company's service, with the information that they had been brought by that company's vessel from Barraud's Inlet, Washington Territory, North-west America. The captain who brought them stated that they were the "backbones" of a gelatinous

fish shaped like a conger eel, which was very common in Barraud's Inlet, and which swam about in shoals along with the dogfishes, that in the living animal these "backbones" were transparent like the rest of the animal, but became ossified when dried on the beach.

Dr. Gray having obtained one of these rods had recently described it as being either the axis of a Pennatulid animal or the "bone of a Cephalopod," under the name *Osteocella septentrionalis*. But Mr. Sclater was of opinion that, supposing the facts above stated to be true, these rods must be regarded as the ossified notochords of some low organized fish with the skeleton wholly cartilaginous, probably belonging to the Lampreys or to the Chimæroid group.

Instinct—with original Observations on Young Animals. *By* D. A. SPALDING *.

With regard to instinct, we have yet to ascertain the facts,—Do the animals exhibit untaught skill and innate knowledge? May not the suppposed cases of instinct be, after all, but the results of rapid learning and imitation? The controversy on this subject has been chiefly concerning the perceptions of distance and direction by the eye and the ear. Against the instinctive nature of these perceptions it is argued that as distance means movement, locomotion, the very essence of the idea is such as cannot be taken in by the eye or the ear—that what the varying sensations of sight and hearing correspond to must be got at by moving over the ground, by experience. The results, however, of experiments on chickens were wholly in favour of the instinctive character of these perceptions. Chickens kept in a state of blindness, by various devices, from one to three days, when placed in the light under a set of carefully prepared conditions, gave conclusive evidence against the theory that the perceptions of distance and direction by the eye are the result of associations formed in the experience of each individual life. Often at the end of two minutes they followed with their eyes the movements of crawling insects, turning their heads with all the precision of an old fowl. In from two to fifteen minutes they pecked at some object, showing not merely an instinctive perception of distance, but an original ability to judge distance and direction with something like infallible accuracy. If beyond the reach of their necks they ran up to the object of their pursuit, and may be said to have invariably struck it, never missing by more than a hair's breadth; this, too, when the specks at which they struck were no bigger than the smallest visible dot of an *i*. To seize between the points of the mandibles at the very instant of striking seemed a more difficult operation. Though at times they seized and swallowed an insect at the very first attempt, most frequently they struck five or six times, lifting once or twice before they succeeded in swallowing their first food. To take, by way of illustration, the observations on an individual case a little more in detail: a chicken at the end of six minutes, after having its eyes unveiled, followed with its head the movements of a fly twelve inches distant; at ten minutes the fly coming within reach of its neck was seized and swallowed at the first stroke; at the end of twenty minutes it had not attempted to walk a step. It was then placed on rough ground within sight and call of a hen with chickens of its own age. After standing chirping for about a minute, it went straight towards the hen, displaying as keen a perception of the qualities of the outer world as it was ever likely to possess in after life. It never required to knock its head against a stone to discover that there was "no road that way." It leaped over the smaller obstacles that lay in its path, and ran round the larger, reaching the mother in as nearly a straight line as the nature of the ground would permit. Thus it would seem that prior to experience the eye, at least the eye of the chicken, perceives the primary qualities of the external world—all arguments of the purely analytical school of psychology to the contrary notwithstanding.

No less decisive were experiments on hearing. Chickens hatched and kept in the dark for a day or two, on being placed in the light nine or ten feet from a box in which a brooding hen was concealed, after standing chirping for a minute or two, uniformly set off straight to the box, in answer to the call of the hen, which

* Printed *in extenso* in 'Macmillan's Magazine,' March 1873.

they had never seen and never before heard. This they did, struggling through grass and over rough ground, when not yet able to stand on their legs. Again, chickens that from the first had been denied the use of their eyes by having hoods drawn over their heads while yet in the shell, were, while thus blind, made the subjects of experiment. These, when left to themselves, seldom made a forward step, their movements were round and round and backward; but when placed within five or six feet of the hen-mother, they in answer to her call became much more lively, began to make little forward journeys, and soon followed her by sound alone, though of course blindly. Another experiment consisted in rendering chickens deaf for a time, by sealing their ears with several folds of gum-paper before they had escaped from the shell. These, on having their ears opened when two or three days old, and being placed within call of the mother, concealed in a box or on the other side of a door, after turning round a few times ran straight to the spot whence came the first sound they had ever heard. Clearly of these chickens it cannot be said that sounds were to them at first but meaningless sensations.

One or two observations favourable to the opinion that animals have an instinctive knowledge of their enemies may be taken for what they are worth. When twelve days old, one of my little *protégés*, running about beside me, gave the peculiar chirr whereby they announce the approach of danger. On looking up, a hawk was seen hovering at a great height overhead. Again, a young hawk was made to fly over a hen with her first brood of chickens, then about a week old. In the twinkling of an eye most of the chickens were hid among grass and bushes; and scarcely had the hawk touched the ground about twelve yards from where the hen had been sitting, when she fell upon and would soon have killed it outright. Even more striking evidence was furnished by a young turkey. When ten days old, it heard the voice of the hawk for the first time, and just beside it. Like an arrow from the bow it darted off in the opposite direction, and crouched in a corner, remained for ten minutes motionless and dumb with fear. Out of a great number of experiments with chickens and bees, though the results were not uniform, yet in the vast majority of instances the chickens manifested instinctive fear of these sting-bearing insects.

But to return to examples of instinctive skill and knowledge, concerning which I think no doubt can remain. A very useful instinct may be observed in the early attention that chickens pay to their toilet. As soon as they can hold up their heads, when only from four to five hours old, they attempt dressing at their wings, that, too, when they have been denied the use of their eyes. Another incontestable case of instinct may be seen in the art of scraping in search of food. Without any opportunities of imitation chickens begin to scrape when from two to six days old. Most frequently the circumstances were suggestive, at other times, however, the first attempt, which generally consisted of a sort of nervous dance, was made on a smooth table. The unacquired dexterity shown in the capture of insects is very remarkable. A duckling one day old, on being placed in the open air for the first time, almost immediately snapt at and caught a fly on the wing. Still more interesting is the art of catching flies peculiar to the turkey. When not a day and a half old, I observed a young turkey, which I had adopted while yet in the shell, pointing its beak slowly and deliberately at flies and other small insects without actually pecking at them. In doing this its head could be seen to shake like a hand that is attempted to be held steady by a visible effort. This I recorded when I did not understand its meaning; for it was not until after that I observed that a turkey when it sees a fly settled on any object steals on the unwary insect with slow and measured step, that when sufficiently near it advances its head very slowly and steadily until within an inch or so of its prey, which is then seized by a sudden dart. In still further confirmation of the opinion that such wonderful examples of dexterity and cunning are instinctive and not acquired, may be adduced the significant fact that the individuals of each species have but little capacity to learn any thing not found in the lives of their progenitors. A chicken was made from the first and for several months the sole companion of a young turkey; yet it never showed the slightest tendency to adopt the admirable art of catching flies that it saw practised before its eyes every hour of the day.

The only theory in explanation of the phenomena of instinct that has an air of science about it is the doctrine of inherited association. Instinct in the present generation is the product of the accumulated experiences of past generations. Great difficulty, however, is felt by many in conceiving how any thing so impalpable as fear at the sight of a bee should pass by inheritance from parent to offspring. It should be remembered, however, that the permanence of such associations in the history of an individual life depends on the corresponding impress given to the nervous organism. We cannot, strictly speaking, experience any individual fact of consciousness twice over; but, as by pulling the bell-cord to-day we can, in the language of ordinary discourse, produce the same sound we heard yesterday, so, while the established connexions among the nerves and nerve-centres hold, we are enabled to live our experiences over again. Now, why should not these modifications of brain-matter (that, enduring from hour to hour and from day to day, render acquisition possible) be, like any other physical peculiarity, transmitted from parent to offspring? That they are so transmitted is all but proved by the facts of instinct, while these in their turn receive their only rational explanation in this theory of Inherited Association.

Notes of a Deep-sea Dredging-Expedition round the Island of Anticosti, in the Gulf of St. Lawrence. *By* J. F. Whiteaves, *F.G.S.*

Through the kindness of the Hon. Peter Mitchell, Minister of Marine and Fisheries for the Dominion of Canada, who not only gave the author facilities for dredging on board Government vessels, but caused rope enough to be placed at his disposal to enable him to examine the greatest depths, the expedition, of which a brief descriptive *résumé* is here offered, was undertaken. Five weeks were spent at sea, and depths of from 100 to 250 fathoms were successfully explored during the months of July and August 1871.

The area investigated includes an entire circuit of the island of Anticosti, as far to the N.W. as Point des Monts (on the north shore of the River St. Lawrence), and to the S.W. as the Magdalen Islands. It was the author's intention to have tried to dredge in the deepest part of the gulf, in a spot situated halfway between the east end of the island of Anticosti and the Bird Rocks, where, according to the Admiralty charts, the bottom is 313 fathoms deep. Unfortunately, however, when this particular point was reached, and every thing got ready, a gale from the N.W. sprung up, which made dredging quite impracticable.

Attempts were made (by using a common thermometer with a metal case and perforated base) to ascertain the temperature of the deep-sea mud. When immersed in the mud, and the whole carefully shaded, the mercury sank almost invariably to 37° or 38° Fahr. The word "almost" is used advisedly; for deep-sea mud brought up from 200 fathoms, in the centre of the river, between Anticosti and the south shore, on one occasion, only made the mercury fall to from 42° to 45° Fahr. Sand brought up from 25 fathoms on the north shore also made the mercury sink to about 37° or 38° Fahr.

It is estimated that upwards of 100 species of marine invertebrates new to the Gulf of St. Lawrence were collected. Of these, 30 or 40 have never been taken before on the American side of the Atlantic, and several are new to science. The number is made up as follows:—

Foraminifera	12
Polycystina	3
Sponges	5
Hydrozoa (about)	10
Actinozoa	4
Echinodermata	2
Annelida (at least)	20
Crustacea	10
Polyzoa	12
Mollusca	24
	102

The Hydrozoa and Annelida have not yet been determined, and only a small portion of the Foraminifera have been critically examined.

The following is a brief descriptive sketch of a few of the most interesting specimens collected. More minute details of the results of the Expedition will shortly be published by the author.

The most curious of the Foraminifera is a *Marginulina*, about ⅛ of an inch in length, from the first chamber of which spinous processes project at various angles. These vary in number in the two specimens collected, and when perfect were probably as long as the shell itself.

Among the sponges are *Grantia ciliata* of O. Fabricius (the first sponge with calcareous spicules recorded from the Gulf of St. Lawrence), a fine species of *Polymastia*, and a massive *Halichondria* with retentive bihamate spicules. Among the Actinozoa the most conspicuous novelty is a beautiful species of *Pennatula*, near to the European *P. phosphorea*, but sufficiently distinct from it, for which the author proposes the name *Pennatula canadensis*. Upwards of forty living examples were dredged in deep water, some of which are 8 inches long. The genus is new to the American side of the Atlantic. Other interesting Cœlenterates from the deep sea are a little social anemone, a species of *Zoanthus*, a new genus of Alcyonoids near to *Cornularia*, and *Eunephthya glomerata*, the latter only known previously from Greenland and the banks of Newfoundland. Two rare echinoderms were collected: one of them is a well-known Norwegian heart urchin, the *Brissus fragilis* of Düben and Koren, the *Schizaster fragilis* of more modern writers: the other, Prof. A. Agassiz informs the author, is the "curious Asterid allied to *Pteraster*" which Prof. Wyville Thomson named *Calveria hystrix*; the name has, however, been proposed for two widely different species in the same journal. The Canadian starfish Prof. A. Agassiz thinks may be the *Solaster furcifer* of Düben and Koren.

No large crabs or lobsters were taken in deep water. The group is only represented apparently in the greater depths by a few curious arctic shrimps. In 125 fathoms, off Cap-Rosier lighthouse, fine specimens of *Nymphon giganteum*, Goodsir, and *Munnopsis typica* of Sars were taken. Several living examples of a *Pycnogonum*, undistinguishable from the European *P. littorale*, were brought up by hempen tangles from 212 fathoms.

The deep-water Polyzoa are very interesting and curious. The most striking among them are:—*Defrancia lucernaria*, Sars; *Retepora cellulosa*, var. *elongata*, Smitt; *Flustra Barleei*, Busk; *Bicellaria ciliata*, Linn.; and *Alcyonidium gelatinosum*, Pallas.

With the exception of a purple *Botryllus*, apparently new, the few Tunicates obtained are well-known northern New-England species.

The following species of shells collected are new to the western side of the Atlantic:—

Arca pectunculoides, *Scacchi.*	Utriculus hyalinus, *Turton.*
Portlandia frigida, *Torell.*	Dentalium abyssorum, *Sars.*
„ lucida, *Lovén.*	Siphonodentalium vitreum, *Sars.*
Astarte, two new species.	Eulima stenostoma, *Jeffreys.*
Neæra arctica, *Sars.*	Sipho spitzbergensis, *Reeve.*
„ lucida, *Lovén.*	„ Sarsii, *Jeffreys.*

The following rare species were also dredged in various localities:—

Terebratula caput-serpentis?	Philine quadrata, *Wood.*
„ spitzbergensis, *Dav.*	Lacuna glacialis, *Möller.*
Pecten grœnlandicus, *Chemn.*	Rissoa carinata, *Mighels.*
Lima subauriculata.	Rissoella eburnea, *Stimps.*
Portlandia thraciæformis, *Storer.*	Buccinum cyaneum?, *Brug.*
Dacrydium vitreum, *Möller.*	„ ciliatum, *O. Fab.*
Astarte lactea, *Brod. & Sow.*	Fasciolaria ligata, *Mighels.*
Macoma inflata, *Stimps. MSS.*	Trophon craticulatus, *O. Fab.*

Three small fishes were on separate occasions taken in the dredge. Of these, one is a small example of the Norway haddock (*Sebastes norvegicus*), one a young wolf fish (*Anarrhichas lupus*), and the other a gurnard of the genus *Agonus*.

Nearly all the marine invertebrates of the northern part of the Gulf of the St. Lawrence are purely arctic species.

Three fourths of the Mollusca of Greenland, for example, range as far south as Gaspé Bay. Quite a number of characteristic New-England species are found off the coasts of Nova Scotia and New Brunswick: a few of these, such as the oyster, find their northern limit in the southern part of the Bay of Chaleurs.

An irregular line of shallow soundings extends from near the northern extremity of the island of Cape Breton, round the Magdalen group, and thence in a westerly direction to Bonaventure Island. To the north, north-east, and north-west of this line the water deepens suddenly, and perhaps even precipitously. To the south and south-west of this line the water is shallow, and never exceeds 50 fathoms in depth. Principal Dawson suggests that possibly the Subcarboniferous limestone (of which the Magdalen Islands are composed, and which appears again on the main shore in Bonaventure County and elsewhere) may crop up under the sea in this shallow area. The line of shallow soundings may form a natural barrier to those arctic currents, if there be such, which sweep down the straits of Belle Isle in a south-westerly direction, and may deflect their course in a bold curve into and up the river St. Lawrence. In the same way this line may form the separation between a purely arctic fauna and one of a more southern character.

The species which belong exclusively to the deep sea in Canada have a decidedly Scandinavian aspect. Most of the specimens collected, which are new to the American side of the Atlantic, are well-known Norwegian, Spitzbergen, or Scotch species.

It is proposed to continue these investigations through the present summer, the Canadian Government having voted a small sum of money to defray the expenses of the expedition.

Anatomy and Physiology.

Address to the Department of Anatomy and Physiology.
By Professor Burdon Sanderson, *M.D., F.R.S.*

We are met here for the purpose of hearing papers on Anatomy and Physiology. It would not have been inappropriate to have given you some account of the limits of the two very distinct sciences which are so designated; but as I am anxious to occupy your time for as short a period as possible, I shall content myself with saying that the few observations I have to make will have reference only to the science to which I am myself attached. I make this preliminary explanation, for the positions of the two sciences in England are so different that much that I may say about Physiology is not applicable to Anatomy.

I should have been glad if it had been possible to have occupied the time in giving you a retrospective account of the progress of physiological research during the past year. I had intended to do so, but was led to abandon my intentions on the ground that although the work done has not been inconsiderable, we in England have taken very little part in it. If I had attempted the task, I should have been but chronicling the doings of our friends in Germany, who are now holding their own scientific assembly in Leipzig. As I do not wish to talk about German physiologists to-day, I find it more agreeable and more encouraging to look forward than to look back; for although we English physiologists (I say physiologists advisedly, because the anatomists are not in the same position) must admit with regret that we have had very little to do with the unprecedented development of our science during the last two decades, we do not intend to continue in the same inactive condition in future.

Considering that half the purpose of our meeting in this Section is to promote the progress of physiology, I do not think I can more properly occupy your time than in endeavouring to show in what direction efforts must be made to improve its position, and particularly to secure a future more fruitful of substantial results than the past has been.

I shall begin by asserting a general principle, which, as I go on, I shall endea-

vour to justify—that one great reason why physiological research is less successfully pursued in England than we could wish it to be, lies in the general want of scientific education. In illustration of this position, I shall refer first to that higher training which is required for the production of scientific workers or investigators; secondly, to what may be called the education of public opinion, by the popularizing agency of books and lectures; and, lastly, to the introduction of Natural Science as an element of education in our great schools and universities.

If a man wants to be a physiologist he must, as things at present stand, study medicine. There is no logical reason for this; for although medicine ought to be built on physiology, there is no reason why a physiologist should know any thing about the art of curing diseases. Practically, however, it is the case that the kind of education which a man requires in order to be a physiologist is best obtained through a course of medical study. I confess myself to be of the opinion that this close relation between medicine and physiology is likely to be a permanent one, on the general ground that any science is likely to be studied with more earnestness by those who have to practise an art founded upon it than by others. For example, in England there can be little doubt that it is to our preeminence over all countries in the mechanical arts that our possession of exceptionally great men in the physical sciences on which those arts are built is due. The reason why the same sort of beneficial reaction of art upon science has not manifested itself in our own sphere is, that the connexion between the two, *i. e.* between physiology and medicine, is much less substantial. We physiologists are not yet in a position to advise the doctors, and they, resting on the more reliable teaching of experience, are quite willing to do without us.

If I am right in supposing that the pursuit of physiological research will always be closely connected with medical study, it becomes a matter of interest to us to know in how far the existing institutions for teaching are fitted for the training of scientific men.

We who are personally concerned in the teaching of medicine must, I think, admit that, as regards English schools, an ordinary medical course is not a very good preparation for scientific work. The reason of this is that the "medical sciences," as they are called—chemistry, anatomy, and physiology—have developed far too fast for the resources of our schools. Physiology, which twenty years ago might (without very flagrant absurdity) have been called the handmaid of medicine, has become a great science quite independent of the art which brought her into existence. No longer learning from medicine as she used to do, but based entirely on experiment, she claims much closer relationship with the other experimental sciences, and particularly with physics and chemistry, than with her parent art.

Let us suppose ourselves carried back, say twenty years. Twenty years ago a lecture-room, with a gallery for showing preparations under the microscope, was all that was thought necessary for teaching physiology, even in the best appointed schools; but then how different was that time from the present as regards the position of the science. I can only refer to one or two of the directions in which progress has been made. Take, for example, the exchange of gases in respiration. In 1852 all that we knew on this subject was founded on the imperfect methods and analyses of the physicist Magnus. Now Ludwig and his pupils have put us in possession of a knowledge which for exactitude may be compared with that of the fundamental facts of physics. In 1852 Ludwig had but lately written his earliest papers on arterial pressure, and had thus, by the introduction of new methods, inaugurated a new era in the physiology of the mechanical functions. Du Bois-Reymond had scarcely begun that series of researches by which he, like Ludwig, rather founded a new science than extended the limits of an old one. In France Brown-Séquard had discovered the functions of vasomotor nerves, and Bernard the glycogenic function of the liver.

Great as was the intrinsic value of all these investigations, it was surpassed by that of the influence which they exercised on the future progress of science. How rapid that progress has been may be readily judged of by any one who chooses to read any of the text-books of twenty years ago in the light of recent researches.

With the exception of the somewhat obscure region of what is called animal chemistry, every chapter has been rewritten on the sure basis of direct observation and experiment—the mechanics of the circulation, the chemical changes in the blood and tissues in respiration, the relation between muscular movements and the central organs of the nervous system which preside over them, the electrical changes which go on in nerves and muscles when in and out of action, and, in physiological histology, the mode of central and peripheral termination of nerve-fibres, and the anatomy of the lymphatic glands and the mode of origin of the absorbent system in the tissues.

In this great progress one would rather not have to admit that Germany has done so large a proportion of the work. France, notwithstanding her great leaders in science and her great scientific institutions, has accomplished much less than she ought to have done. In taking her part, England has been represented by us, the teachers in her medical schools; but we, possessing neither space nor appliances for the prosecution of experimental inquiries, have contented ourselves only too readily with reaping the fruits of other men's labours.

It would not be pleasant to make this admission, were it not possible to look forward with considerable confidence to something better. In the great medical schools of London, in the old universities, and in one or two, at least, of the provincial schools great efforts are now being made to provide adequate buildings and competent persons for the experimental teaching and study of physiology. It is, I think, a most encouraging sign of the times that the initiative in this movement has been taken by Trinity College, Cambridge. That wealthy corporation, whose very name recalls to our recollection the intellectual glories of our country, has condescended to provide a place for physiologists to study and labour in, from which (short as the time is during which it has existed) one or two valuable researches have already sprung. To what the University of London has done during the last twelve months, in establishing a laboratory for inquiries into that most important though comparatively new branch of physiology which relates to the origin and nature of diseases, it is scarcely possible for me to refer, excepting in so far as to express my hope that its influence will eventually be felt in strengthening the hold of physiology on practical medicine.

Notwithstanding these efforts, it will take years to regain the position which we in England once had, and ought never to have lost. The appliances and places for work are now forthcoming, and can be extended as they are required. This is a great step forwards; but we still want the pecuniary resources requisite for carrying out systematic and continuous researches, and, above all, we have still to educate workers.

Of the two wants I have mentioned, the want of money and the want of workers, the second is the most important. The difficulties which lie in our way in this respect are very great indeed. The obvious difficulty—the objection, I mean—which is always adduced by young men as a sufficient reason for not giving up their time to scientific research is that it does not pay; but it need scarcely be said that the real difficulty is a more general one. It lies in that practical tendency of the national mind which leads us Englishmen to underrate or depreciate any kind of knowledge which does not minister directly to personal comfort or advantage, a tendency which was embodied in the philosophy of Bacon, and has been thought by some to constitute its great weakness. I have no doubt there are as many in England as in Germany who would not be deterred by the prospect of comparative poverty, which in every country must be the part of those who devote themselves to abstract science; but there are very few who have the courage and resolution to follow this course in spite of a public opinion, which estimates science on utilitarian principles.

This leads me naturally to my second point, which is that the most efficient means we can take to improve the position of our science in England are those which have for their object the enlightenment of public opinion, and that this is to be effected partly by diffusing this knowledge of our labours among the public, and so inducing them to take an interest in them, partly by introducing training in physical science into our schools.

In the art of exposition, *i.e.* of making difficult subjects plain, we have one

among us who is a master—whose powers in this respect have been acknowledged, not only in England, but in France, and still more emphatically in Germany. His work on elementary physiology has been presented to the German public by one of the leading German physiologists (who is himself a model of clearness of style), who tells his countrymen in his preface that no German writer could expound the experimental facts which are the basis of physiological knowledge as Huxley can.

In the existence of such a man as Huxley I find a great source of encouragement for the future of English physiology, not only on account of his own work, large though that has been (for no one builder can lay many bricks in an edifice where every brick requires such careful laying), but also for his influence on national life.

At one time I confess that I was disposed to underrate the value of popularizing science; now I see the power of exposition to be a great power for good. We have an example of the good it effects in the history of this Association. We have another in that of the Royal Institution, which has lately been made familiar to us by the accounts which have been given of that great and good man who for so many years was its life. Faraday, the greatest physicist of his time, was equally master of the art of exposition. Of the influence which his mind thereby exercised on the minds of men, women, and children there can be no doubt. Nor do I think that he lost by it himself; for although we cannot suppose that he taught without some exhaustion of his energies, I cannot believe that the effort was a useless one even to himself.

One would not venture to say of such a man that, in explaining to children the fundamental conceptions which in his mind were already so clear, these became still clearer; but I think it may be so.

I pass at once to the third part of my position, that which relates to the teaching of science, and particularly physiology, in schools. This I may deal with very shortly.

The teaching must necessarily be elementary. If it is thorough and genuine, it is good.

To wedge a little bit of Bowdlerized physiology, something about the structure and functions of the human body, into the ordinary course of a school education may be an ornamental addition to it, but can scarcely be really useful. Our reform, if it is to be attempted at all, must be much more complete and radical. It must consist, not in adding natural science to the system of instruction in which we ourselves and our predecessors were brought up, but in substituting for some of the old drudgeries something better and more substantial.

As regards that higher education which may be defined as introductory to the studies of the University, most people are now disposed to recognize that there exists at the present day a tendency to increase its extent at the expense of its thoroughness. On the one hand a powerful effort is made by the *laudatores temporis acti* to maintain the old disciplines; while on the other a general though somewhat vague notion prevails that no system of education can be regarded as complete from which science is excluded. To reconcile these antagonistic tendencies, the only method which has been found is that of addition and accumulation. Instead of displacing some of the old requirements, an additional load of new subjects has been imposed on the unfortunate examinee, in the form of chemistry, physics, animal physiology, &c. No wonder that to the victim who has just passed through one of our modern ordeals the very names of these sciences are sickening; for in addition to the disagreeable task of getting them up from text-books (text-books, however excellent, are at best but very poor reading), the competitor, whether successful or not, has the consoling reflection that he has been doing treadmill work after all—learning a number of facts and laws of great value to the man who is able to possess himself of them, but to him rendered absolutely useless from the mode of study to which the present system of examinations has compelled him.

The way to obviate this I have already hinted at. Let it be clearly understood that if natural science is to be made a part of our educational system, it cannot be introduced as an ornamental addition or accomplishment, but as part of the ground-

work. To serve as a groundwork, we must admit that physiology and anatomy are not adapted.

The corner-stone must, of course, be mathematics. Side by side with mathematics the subjects which ought to claim preference are physics and chemistry. The latter, when taught and studied experimentally, is specially fitted to cultivate that certainty, that convincedness of mind, that clear realization of facts seen not by the bodily but by the intellectual eye, which constitute the scientific spirit. A boy who has learnt to feel the certainty of the laws of chemical combination can never, so long as he retains his mental soundness, relapse into that state of vague indifference about facts which characterizes many uneducated persons, or lose the habit of exactitude of conception and statement to which he is compelled by practice in chemical reasoning.

It is clear that anatomy and physiology cannot be recommended on the same ground; yet I believe that it may be wisely included in ordinary education, not as a discipline, and not as a subject of examination, but on the ground that it is so usefully applicable to the common affairs of life. It is undoubtedly useful that every one should know something of the structure and functions of his own body; and this for several reasons: first, because he is enabled thereby to take better care of himself, and to understand how to preserve himself by reasonable precautions against some of the well-recognized causes of disease. Another reason is, he is thereby rendered not so liable as he would otherwise be to become the dupe of the many quackeries which are afloat—more ready to take the advice of the doctor as regards the regulation of his mode of life, less credulous about the efficacy of drugs.

Let us now, in conclusion, say one word as to the influences which the general adoption of a system based upon scientific training would exercise on scientific progress, and particularly on the progress of the science in which we are interested.

I can illustrate this best by taking the medical student as an example. We teachers of physiology to medical students know that when we begin first to talk to them about the principles of the subject (*e.g.* about chemical change as the essential condition of all vital phenomena, about the relation between the production of heat and external motion, about the exchange of gases in respiration, and many other fundamental subjects) the great difficulty is that our auditors are utterly at fault for want of those conceptions about matter and its powers which are expressed by the words we are constantly using, such as solid, liquid, gas, vapour, weight, density, volume, &c., all of which to the average finished schoolboy are perfectly meaningless. The result is that these fundamental conceptions, not having been mastered at first, are not mastered at all, and the student begins to build the superstructure without having had any opportunity of laying the foundation. If the *Vorbildung* were different, if students were to come to their work with the scientific habit of mind already formed, it would not only make them better students, but would retain its influence on them through life. The details might fade from the memory, but the spirit would remain.

I trust that it will not appear to the members of the Section that I have, in any of the observations I have made, forgotten that the object for which we are assembled here is the promotion of the science of anatomy and physiology. Although I cannot claim for our science a more direct interest in scientific training than for others, there are reasons (as I have endeavoured to show) why it suffers more from the want of it than others—the chief one being that, as compared with what we feel and know to be its real importance to the future welfare of humanity, the practical benefits which immediately arise from it are not very obvious.

I have said very little indeed of another pressing difficulty which we have now and, I believe, will have for many years to contend with—the want of pecuniary resources; because I know that in this country if educated public opinion can be interested on behalf of any scientific object, and particularly if the intelligent classes of the community can be shown, on good ground, that the furtherance of abstract science is a matter of vital importance to our national existence, the really trifling public expenditure which would be required to enable us to compete at least on equal terms with Germany, Austria, Bavaria, and Russia will at once be forthcoming.

In the mean time it is the function and duty of all who have the means and are interested in scientific progress, and especially of us, the members of this Section of the British Association, to afford such aid as we can to those who, supported by their own enthusiasm rather than by the prospect of honour or emolument, are willing to devote their lives to physiological and anatomical researches.

On the Arrangement and Nomenclature of the Lobes of the Liver in Mammalia. By Prof. W. H. Flower, *F.R.S.*

The descriptions of the livers of various animals to be met with in treatises or memoirs on comparative anatomy are generally very difficult to understand for want of a uniform system of nomenclature. The present communication, which endeavours to supply such a system (and was illustrated at the Meeting by a large series of coloured diagrams), is based upon an examination of the condition of the organ in examples of every important subdivision of the class. The difficulty usually met with arises from the circumstance of the liver being divided sometimes, as in man, ruminants, and the cetacea, into two main lobes, which have always been called respectively right and left; and in other cases, as the lower monkeys, carnivora, rodentia, &c., into a larger number of lobes. Among the latter, the primary division usually appears at first sight to be tripartite, the whole organ consisting of a middle, called "cystic" or "suspensory" lobe, and two lateral lobes, called respectively right and left lobes. This introduces confusion in describing livers by the same terms throughout the whole series of mammals, as the right and left lobes of the monkey or dog, for instance, do not correspond with the parts designated by the same names in man and the sheep. There are, moreover, conditions in which neither the bipartite nor the tripartite system of nomenclature will answer, which we should have considerable difficulty in describing without some more general system.

It appears desirable to consider all livers as primarily divided by the umbilical vein into two segments, right and left. This corresponds with its development, and with the condition characteristic of the organ in the inferior classes of vertebrates. The position of this division can almost always be recognized in adult animals by the persistence of some traces of the umbilical vein in the form of the round ligament, and by the position of the suspensory ligament.

When the two main parts into which the liver is thus divided are entire, they may be spoken of as the right and left lobes; when fissured, as the right and left segments of the liver, reserving the term lobe for the subdivisions. This will involve no ambiguity, for the terms right and left lobes will no longer be used for divisions of the more complex form of liver.

In the large majority of mammals each segment is further divided by a fissure, more or less deep, extending from the free towards the attached border, which the author proposed to call *right* and *left lateral* fissures. When these are more deeply cut than the umbilical fissure, the organ has that tripartite or trefoil-like form just spoken of, the part between them being the so-called middle, cystic, or suspensory lobe. These terms the author proposed to discontinue, and to institute *right central* and *left central* for the two regions included between the umbilical and the two lateral fissures, and to use *right lateral* and *left lateral* for the regions beyond the lateral fissures. The essentially bipartite character of the organ, and the uniformity of its construction throughout the class, is thus not lost sight of, even in the most complex forms.

The left segment of the liver is rarely complicated to any further extent, except in some cases by minor or secondary fissures marking off small lobules, generally inconstant and irregular, and never worthy of any special designation. The principal differences to be noted depend on the degree of completeness of the lateral fissures (which sometimes extend quite across the hepatic tissue, completely severing the left lateral lobe) and the relative size of the two lobes.

On the other hand, the right segment is usually more complex. The right lateral fissure when fully developed passes into the right extremity of the portal

fissure. The right central lobe, therefore, on its under surface does not reach to the attached border of the liver, but is always bounded in that direction by the portal fissure. Moreover, the gall-bladder when present is always in relation to its under surface. The position of this receptacle with respect to the lobe may vary; sometimes it is merely applied to its surface, loosely connected by connective tissue; in other cases it is deeply imbedded in a fossa. Very often it is placed near the middle of the lobe; sometimes close to one or the other of its lateral boundaries. In many cases the fossa in which the gall-bladder is sunk is continued to the free margin of the liver as an indent, or even a tolerably deep fissure. This is called the cystic fissure; but, in consequence of its irregularity of position and frequent absence, it is not of the same importance as the other fissures which have been named, and does not mark off any distinct divisions of hepatic substance.

The right lateral lobe always has the great vena cava either grooving its surface or tunnelling through its substance near the inner or left end of its attached border; and a prolongation to the left, between the vein and the portal fissure, has long been known under the name of the *Spigelian lobe*. This is always a distinct hepatic region, sometimes a mere narrow flat track, but more often a prominent tongue-shaped process. Whatever may be its form, it is bounded in front, or towards the free surface of the liver, by the portal fissure; on the left by the fissure of the ductus venosus (unless the vessel is bridged over by hepatic substance); posteriorly and partially on the right by the vena cava, but between this vessel and the right end of the portal fissure it is continued onwards into the adjoining part of the right lateral lobe.

The main body of the right lateral lobe is most commonly divided into two parts, not by a cleft, such as the lateral fissures, passing from the upper to the lower surface of the liver, but by one which severs a part off from the under surface. This is the *caudate lobe*; and the fissure which separates it from the right lateral lobe may be called the "fissure of the caudate lobe." In man it is almost obsolete; but in most mammals it is of very considerable magnitude, and has very constant and characteristic relations. It is connected by an isthmus at the left (narrowest or attached end) to the Spigelian lobe, behind which isthmus the vena cava is always in relation to it, channelling through or grooving its surface. It generally has a pointed apex, and is deeply hollowed to receive the right kidney, to the upper and inner side of which it is applied *.

On Pulse-Rate and the Forces which vary it. *By* A. H. Garrod.

The number of the heart's beats can be proved to depend on variations in the resistance offered to the flow of blood through the small arteries, and not at all on the blood-pressure. Poiseuille showed that the flow of fluids through capillary tubes varies directly as the pressure. From these facts it can be proved that to maintain a uniform circulation, such as the systemic, it is essential that the capacity of the arterial system, including the heart, must vary directly as the blood-pressure; and therefore it is necessary that the heart always recommences to beat when the tension or pressure of the blood has fallen a certain invariable proportion, and then only. The known variations in pulse-frequency in health are all explicable on this supposition, for they can be proved to be caused by modifications in the arterial peripheral resistance; thus while standing the body-weight is supported by rigid tissues, but while lying soft parts are compressed, and therefore resistance is introduced. The next point considered is the cardiograph law of the author; and an explanation is given of its significance, which leads to the results that the nutrition of the heart varies directly as the blood-pressure and as the square root of the time of nutrition. Reasons are also given to show that the cardiac revolution must be divided into three instead of two parts,—first, systole; next, diaspasis, or the valve closure interval; and, lastly, the diastole.

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* For a figure explanatory of the above paper, see 'Nature,' Aug. 29th, 1872.

The Concurrent Contemporaneous Progress of Renovation and Waste in Animated Frames, and the extent to which such Operations are controllable by Artificial Means. By GEORGE HARRIS, *F.S.A., Vice-President of the Anthropological Institute.*

The writer, after throwing out a suggestion as to what a perfect system of pathology might be expected to comprehend in a precise and complete knowledge of the cause of each disease, and also the counteracting remedy to be applied for its cure, proceeded to remark that corresponding questions arose with regard to renovation and waste, as to whether the causes which affect them are capable of control, although we are unacquainted with many of them, or whether they are such as to be entirely beyond control. He adverted to the ascertained fact of the progress of renovation and waste in all animated frames, as also to the circumstance that certain of these operations were known to be controllable. He analyzed the principle of waste and decay in different bodies, both substantial and liquid, and observed that the fact of bodies being animated did not exempt them from the laws of nature. Extraordinary longevity had been attributed to certain wild animals; and it was remarkable that they were seldom found in a state of decrepitude from old age. Savages derived from observation of wild animals the medicinal properties of many plants and springs. Ossification of the bones and deterioration of the blood had been considered by Buffon* and Smellie † to be the main causes of waste and decay in animated frames. The opinions of Galen, Willis, Hunter, and other authorities, ancient and recent, were cited. The writer then proceeded to contend that, as the causes both of renovation and waste in certain bodies are ascertained and are subject to control, these causes may be both ascertained and subjected to control in many other cases also, if not universally, and in frames which are animate as well as those which are inanimate. If you can retard waste of the same nature with ossification, you can retard ossification also; and if you can retard ossification to a limited degree, according to our present limited means and knowledge, when that means and knowledge become more extended, your power to control waste must necessarily be to a corresponding degree extended as well. So also as regards the condition of the blood, and our control over that condition. As science advances these causes may be better understood, and the properties of various substances to control them at length perfectly ascertained. He recommended experiments of various kinds as to the nature of substances and their effect on bodies, animate as well as inanimate, and with regard to animals and plants as well as man, as essential to solve this great problem satisfactorily.

On the Mechanism of the Change of Colour in Fishes and Crustacea. By M. G. POUCHET.

As is already well known, the change of colour is due to the change in size of contractile coloured cells placed in the skin. These are under the influence of nerves. The author found that the particular nerves controlling them (in the turbot) were nerves of the sympathetic. By cutting the nerve supplying a particular area of the skin, he had been enabled to retain that area unchanged in colour, whilst the rest changed according as the fish found itself on a light or a dark surface. That the eye is the means by which the change in its conditions is communicated to the fish or crustacean, and that then a reflex action takes place, acting through the sympathetic nerves on the colour-cells of chromatophors, is proved by the fact that when the animal experimented on is blinded, no further change of colour occurs when it is removed from light to dark or dark to light surroundings.

On the Mechanism of Muscular Contraction. By DR. RADCLIFFE, *F.R.S.*

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* Histoire Naturelle de l'Homme. † Philosophy of Natural History, p. 509.

On the Graft Theory of Disease.
By James Ross, *M.D., Waterfoot, near Newchurch.*

The active part of virulent fluids has been proved by the experiments of Prof. Chauveau and those of Dr. Burdon Sanderson to reside in particles not larger than the $\frac{1}{20000}$ of an inch in diameter. These particles are admitted to be living; and the question arises whether they form a race of independent beings like *Bacteria,* or are merely modifications of the organism from which they have become detached. The former view constitutes the basis of what is called the germ-theory of disease, while the latter view is adopted here; and this constitutes at once the grounds and the justification of the title—the Graft Theory of Disease. In the absence of direct experimental evidence to decide between these different opinions, our only alternative is to develop as much as possible the indirect evidence. On the supposition that the contagion particles are merely modified portions detached from a living organism, there is a close similarity between them and the reproductive particles. Both sets of particles are merely modified epithelial cells: they also become detached because the supply of nourishment fails them, and both are characterized by being unspecialized. In the reproductive particles there is a union between two particles detached or semidetached; but in the case of the genesis of a contagious disease there is a union between a distinct individual and a detached portion of another individual. In this respect, therefore, the analogy fails. But the phenomena of vegetable grafting agree even in this respect with those of the contagious diseases. Dr. Masters says that "cases have been observed where from the stock below the graft fruits and flowers of the same appearance as those borne on the scion have made their appearance." Again, Mr. Darwin says that "when the variegated jessamine is budded on the common kind the stock sometimes produces buds bearing variegated leaves." This shows that the scion affects the stock not only at the point of contact, but that it communicates to it a change which manifests itself throughout the entire organism of the latter; and this is one of the most remarkable features of contagious diseases.

But if virulent fluids are merely modifications of healthy tissues, the effects produced by them upon another organism should correspond in certain leading particulars to those of other morbid tissues. If we compare the primary pustule in inoculated smallpox with the pustule caused by tartar-emetic ointment, we shall find that they go through a more or less similar evolution. An areola, or inflammatory ring, surrounds them, which is large and well-marked in the former, but is also present in a minor degree in the latter. The former can be communicated by inoculation to a healthy individual, but ordinary inflammation has also been communicated in a similar manner. The lymphatic glands in the vicinity of the smallpox-pustule become swelled, but this is only what occurs in the case of almost all local diseases; and the character of the glandular affection always corresponds with the local disease which has excited it. This is well seen in syphilis, tubercle, and cancer. The lymphatic enlargement in smallpox, therefore, presents no peculiarity which does not occur in other diseases; but in other diseases, such as pyæmia, tubercle, and cancer, secondary affections occur in the lungs, liver, and internal organs generally. The secondary affection in inoculated smallpox, however, takes place on the surface of the body. This is probably owing to the special affinities of the tissues for special substances. It is also necessary in all highly contagious diseases that living particles should be detached in large numbers from the body; hence secondary affections must occur in such diseases on either the external or internal surface of the body, otherwise the disease would die out. The fever is not, of course, peculiar to smallpox: it is always an accompaniment of rapid tissue changes; and the fever is higher in smallpox and the contagious diseases generally, just because there is more rapid cell-multiplication throughout the body. Such changes mean an augmentation of the molecular forces devoted to growth at the expense of those devoted to structure and function, and what is not expended in the latter goes to the genesis of heat. But rapid cell-multiplication involves other morphological changes: these are diminished bulk of units, disappearance of cell-wall, and discontinuous growth; and such are proved to be the characteristics of virulent fluids. Smallpox has, therefore, a close affinity with

those diseases which arise within the body from ordinary changes in the environment; and this is equally true of the other zymotic diseases. On the other hand it might easily be shown that they have very little affinity with the true parasitic diseases. All these considerations tend to show that the germ-theory is inapplicable to the zymotic diseases.

The Cause of the Respiratory Variations of Arterial Pressure. By Dr. BURDON SANDERSON, *F.R.S., Professor of Practical Physiology, University College, London.*

The purpose of this paper was to show experimentally that the rhythmical variations of arterial pressure, and of the frequency of the contractions of the heart, which are normally associated with the respiratory movements, may occur in the absence of those movements, and that they cannot therefore be wholly dependent upon them. This is proved by the observation that in animals which are gradually subjected to the toxic action of curare while the variations of arterial pressure and pulse-rate are continuously recorded on the kymograph, these variations persist after the respiratory movements have ceased.

The experimental results which form the subject of this communication were obtained by the author in the year 1867. They are now published for the first time, by way of supplement to certain recently published observations of Prof. Hering on the subject.

The normal relation between the curve of arterial pressure and that of thoracic expansion and contraction is now well known. In the dog each inspiratory act is followed by an increase of arterial pressure with acceleration of the frequency of the contractions of the heart. During the period of expiration, *i. e.* the interval which separates one inspiration from its successor, the arterial pressure sinks and the pulse becomes much less frequent. In both cases the phenomena relating to the circulation always occur later than the corresponding respiratory movements; so that, *e. g.*, the period of increase of arterial pressure and pulse-frequency always begins and ends later than inspiration, coinciding usually in the dog with the latter half or two thirds of the inspiratory act and the beginning of the act of expiration. Hence the interval between each such period and its successor coincides with the latter part of the expiratory period and the beginning of inspiration, *i. e.* begins a little after each expiration and lasts after the beginning of each inspiration. In a dog previously narcotized by morphia it is possible, by employing a very small dose of curare, to arrest the respiratory movements by such slow degrees that the effect of their gradual cessation on the variations of arterial pressure may be watched in all its stages. For this purpose it is necessary before injecting the curare to connect the carotid or crural artery of the animal with the manometer of the kymograph, and to record the respiratory movements simultaneously on the same cylinder in such a way that the two tracings may be written one above the other, and that their synchronous points may be always in the same vertical line. Tracings so obtained corresponding to various stages in the action of the curare were exhibited. The first showed the character of the arterial and respiratory curves, and their relation to each other before any curare had been given. The second exhibited the state of the circulation when the respiratory movements, although irregular, were still vigorous. At the third period the respiratory movements had become very shallow, and there was a distinct interval between inspiration and expiration: the inspiratory effort was then attended with a slight twitching of the external muscles of the larynx, and expiration with a similar twitching of certain muscles of the limbs. Finally, in the last tracing of the series it was seen that, although the effect of the expiratory effort was no longer perceptible, there was a slight jerk downwards of the lever which represented inspiration.

Corresponding to these successive diminutions of respiratory movements, it was seen that the variations of arterial pressure, although they diminished, did not disappear. Throughout the whole period of observation it was observed not only that the variations of pressure and pulse-rate continued, but that they preserved the same relation precisely to the slight movements which represented inspiration and

expiration. After these movements had entirely ceased they still preserved the same character and rhythm.

From the fact thus proved that the rhythmical variations of arterial pressure and pulse-frequency persist in the curarized animal after the respiratory movements have ceased, the author concludes that these movements cannot be regarded as their cause; and he regards them both as attributable to rhythmical motor impulses originating from the medulla oblongata, in which the three centres which preside over the respiratory movements and those of the circulation alike participate, viz. the centre of the cardiac vagus, the respiratory centre, and the vasomotor centre. He supposes that with each period of increased activity of the inspiratory centre a period of increased activity of the vasomotor centre coincides, and that both of these centres act antagonistically to the centre of the cardiac vagus. Each rhythmical excitation of the respiratory centre determines corresponding excitation of the vasomotor centre, which manifests itself in increase of arterial pressure and suspension of the activity of the cardiac vagus.

The author adheres to the conclusion arrived at from his previous experiments (Phil. Trans. 1868), that in the dog the respiratory movements of the chest exercise a considerable direct and mechanical influence on the heart, and thereby on the arterial pressure.

Experiments relating to the Coagulation of the Blood. By E. A. Schäfer.

In the course of a series of experiments upon the coagulability of frog's blood, performed in the Physiological Laboratory of University College, the author observed the following facts:—

The blood of the frog frequently exhibits, especially during the winter months, but a very slight tendency to coagulate, so much so, that when drawn it not unfrequently remains completely liquid, with the exception of a film in immediate contact with the sides of the glass vessel. On standing such blood soon separates into two layers, the upper a clear plasma, the lower a mass of corpuscles. If undisturbed the blood may remain in this condition an indefinite time without undergoing coagulation; although if a little of the clear supernatant liquid be taken up into a very fine glass tube it speedily solidifies, owing to the large relative amount of surface to which it is exposed.

In a few cases, on the other hand, the blood when drawn coagulates throughout. If examined after a few hours it may appear as if coagulation had not occurred at all, since we have the vessel filled, as before, with fluid blood separated into two strata. In these cases, however, the clear supernatant liquid yields no further coagulum in a fine glass tube, thus showing that it contains no fibrin in solution, *i. e.* that it is *serum*, not plasma; besides, the contracted remains of the clot may always be found. The appearance of reliquefaction of the blood here presented is due entirely to the astonishing amount of contraction which the fibrin undergoes, the result of this contraction being that not only the serum but even the corpuscles themselves are expressed from its meshes*.

That the diminution in bulk of the clot (which may proceed to such an extent as to leave but a slight trace) is due to this cause only, and not to a reliquefaction of fibrin, as v. Recklinghausen supposed, is shown by the fact that when the primary coagulation is complete no further coagulum is obtainable from the serum, even under the most favourable circumstances.

But there is a source of error to guard against. The blood may *appear* to have coagulated throughout, when all the while its central portions may not have participated; indeed this occurs in the majority of cases. It is easy to see that, under such circumstances, when the fibrin contracts the serum which is expressed will have mixed with it a greater or less amount of liquor sanguinis, and hence will be found to be coagulable.

* This process may readily be observed microscopically as it occurs in a very thin-walled capillary tube. An immersion objective should be used for the purpose of observation.

On the Normal and Abnormal Growth of Limnæus. *By* Professor CARL SEMPER.

On the Occurrence of the Supracondyloid Process in Man. By Prof. STRUTHERS, *M.D., of Aberdeen.*

The author showed dissections of this part in several animals. An arch of bone is thrown, like a bridge, over the great nerve, and generally also the great artery of the limb, a little above the elbow, protecting them from pressure and injury. No such structure exists normally in the human arm, but it occurs occasionally as a variation. When it exists, the process grows from exactly the same spot as in animals which possess it, and the arch is completed by a ligament, the nerve and generally also the artery passing under the arch. This variety had attracted some notice lately, and is supposed to be very rare; but the author has found it often, and he exhibited a large number of specimens of it from the human arm, in its various degrees of development. He had also met with it occasionally in the living body, and had lately been able to prove the correctness of his previous supposition that it may be hereditary, having met with it in the members of a family, in the father and in four sons. The author remarked on the great interest attaching to this variation. In animals which possess it, it is what, in olden phraseology, would be called a contrivance specially designed for the protection of the nerve in them. But why should the same contrivance occur as a variety in man? The old argument from final cause, and no less its successor the theory of "type," besides being metaphysical, become untenable in the face of the existence of these rudimentary structures. The theory of so-called type has a great deal to answer for in obscuring the natural interpretation. If species are of independent origin, how comes it that animals have in their bodies parts of other animals, parts which are of no use to them, sometimes even dangerous to them? To those who are able to overcome the prejudices of their early education, the evidence comes with irresistible force in support of the hypothesis of the origin of species by evolution.

On the Sternum and Pelvic Bone in the Right Whale and in Great Fin-Whales. By Prof. STRUTHERS, *M.D.*

The sternum exhibited showed a very different form from that of the same species of Fin-Whale which Prof. Struthers had brought under the notice of the Association last year. Instead of a single median cervical process, it has a deep median notch with a broad crest on each side, and the posterior process is very narrow. Two sterna of the Greenland Right Whale exhibited were large. The author divides the sternum into three parts. The middle, between the first ribs, is thick, completing the thoracic girdle, and essential; the part in front of this and the part behind it vary greatly, being more or less rudimentary. The sternum of the Finner has two joints with the first rib, that of the Right Whale only one joint; and this difference in the thoracic adaptation, together with the great breadth of the first rib in the Right Whale, might explain the very different forms presented by this bone in these two kinds of whales.

One of these breast-bones exhibited marks of former inflammation of the bones. The author mentioned that he had often met with this condition in whales; in some cases ankylosis of the vertebræ had resulted, and in some there must have been considerable suffering to the animal. This fact might be commended to the notice of those, if there be yet any such, who have the notion that disease occurs in animals only when they come under the influence of man.

On the Occurrence of Finger-muscles in the Bottle-nose Whale (Hyperoodon bidens). *By* Prof. STRUTHERS, *M.D.*

This bottle-nose stranded on the Aberdeenshire coast just after the Meeting of the Association last year at Edinburgh, at which the author read an account of the

finger-muscles in the great Fin-Whale, first noticed by Prof. Flower. It had been believed that these muscles do not exist in the toothed whales; but in this bottle-nose they were even better developed than in the Finner. The extensor muscles especially were better marked, the external extensor, corresponding to the so-called extensor of the little finger of man, being also present. An extensor carpi radialis was also present. Besides the muscles which are known to exist at the shoulder and arm in the Cetacea, he found a representative of the biceps present here. These muscles were mainly to be regarded as rudimentary, but they had a certain low amount of function by which their presence as muscles is maintained. In some other cetaceans they are represented entirely by fibrous tissue. Prof. Struthers exhibited also a dissection of the rudimentary teeth concealed in the gum of this bottle-nose. These teeth are alive, but useless, and their presence could be reasonably interpreted only by the hypothesis of evolution.

Anthropology.

Address to the Department of Anthropology. By Colonel A. Lane Fox., *F.G.S., F.S.A.*

When the Council of this Association did me the honour of naming me one of the Vice-Presidents for this Section, and the duty of opening the proceedings of this Department was committed to my charge, I had before me two alternatives, which, I suppose, must have suggested themselves to most of those who have occupied the Chair which I so unworthily fill upon the present occasion. I had to consider whether I should prepare a communication upon some special branch of study to which I had devoted my attention, or taking a broader and more general view of anthropological science as a whole, I should endeavour to offer a few remarks which might be useful in clearing the ground for the valuable and interesting papers which will be presented to you in the course of the session.

In partly adopting the latter or more general course, which I may say is the one that is least congenial to me, on account of my conscious inability to deal satisfactorily with so large a subject, and also because I think that in the present state of our knowledge we are better employed in collecting evidence than in generalizing, I have been influenced chiefly by a consideration of the many and great defects which have been acknowledged to exist in our method of proceeding in this department of science—defects which are, I believe, the natural concomitants of the early stage of development through which we are passing, but which we must set our faces seriously to encounter before we can hope that anthropology will be fairly admitted into the brotherhood of the established sciences which are recognized under the auspices of this Association.

When towards the conclusion of the last Meeting at Edinburgh one of the ladies present drew attention to the generally unscientific character of the papers which had been read, she, I believe, said no more than was strictly applicable, not only to that particular Meeting, but to upwards of two thirds of the papers which are included under the head of anthropology elsewhere; and here I may observe that if no other benefit were recognized from the participation of the other sex in our discussions, we should find in it a source from which home truths of this nature can emanate without their setting our backs up. In making these remarks I am conscious that I am hafting the lash which may perhaps with some justice be applied to your Chairman on the present occasion. I cannot, however, claim any special exemption, but must share with my brother anthropologists any censure which may be justly due to our shortcomings.

The ladies must not, however, be too severe upon us in this department, but must make allowance for the empiricism which is naturally attendant upon a new study; for the anthropology of to-day bears, I believe, about the same relationship to the anthropology of the future that alchemy and astrology did to the chemistry and astronomy of our own times. We have established none of the landmarks, the classifications, or the nomenclature which in other sciences serve to keep the

discussions within bounds, and direct the thoughts of the workers into useful channels. Anthropology is such a vast field of study, it is so impossible for any single mind to comprehend the whole with the precision that is necessary for scientific purposes, that it demands more than any other the subdivisions that are recognized in the sister sciences, but which at the present time are absent in ours. Hence the random range of our discussions; each speaker naturally wanders into the path that is most familiar to him, and there is no sufficient discipline to bring him back into the line of march.

Moreover, in dealing with anthropological subjects we are met with difficulties arising from their closeness relatively to ourselves. The same impediment which in the eye of the law incapacitates a man from judging or even from giving an impartial evidence in his own case meets us at every turn. It is comparatively easy to generalize when dealing with external nature; but when the materials on which we have to work are drawn from the reservoir of human thoughts and actions, we cannot disengage ourselves sufficiently to take a comprehensive view of the subjects we are studying. I presume that even the ablest amongst us must labour under a sense of incapacity in dealing with anthropological speculations. We may be said to stand in the position of molecules of paint upon the surface of a picture striving to catch the artist's design. Is it surprising there should be confusion of tongues in such a Babel as we are building?

Since, then, our anthropological field of vision is so extremely limited, it behoves us all the more in this branch of study to concern ourselves with the arrangement of our subdivisions, in order that they may bear an harmonious relation to each other, and whilst giving full vent to individual thought and action, and limiting the sphere of inquiry in each branch to such matters as may fall within the easy grasp of finite minds, they may at the same time be rendered subordinate to those great general objects which it is the intention of anthropological science to serve; for it cannot be proclaimed too often that in this country and in this Association we have not adopted the term *anthropology* out of deference to any particular dogmas or sets of opinions, or out of regard for any particular party or society, but because that term appears to be etymologically the most accurate for embracing the whole of those many studies which are included in the *science of man*. As one of those who for some years past have taken part in those practical measures which have been as yet only partially and feebly instrumental in promoting the union of the anthropological sciences, it occurs to me that the present occasion may be a fitting one for expressing some of the views which have suggested themselves to me in the course of my experience whilst so engaged. I propose, therefore, after considering briefly the existing phases of one or two of the more important questions with which anthropology has to deal, and saying a few words on the relative value of certain classes of evidence, to speak of the anomalies and misadjustments in what may be called the machinery of anthropological science, defects in the existing constitution of some of the societies which either are or ought to be included amongst the branches of our great subject. In the remarks which I shall offer upon this subject it is not my wish that any undue weight should attach to the particular suggestions which I may be called upon to make as in any way emanating from this chair. My object is rather to draw the attention of anthropologists to the urgent necessity which exists for better organization than to propound any particular schemes of my own; indeed, so rapidly do our views change in the infancy of a science, that I should be sorry to bind myself over to accept many of my own opinions a couple of years hence; for there is, perhaps, no branch of study to which we may more truly apply the dictum of Faraday, that "the only man who ought really to be looked upon as contemptible is the man whose ideas are not in a constant state of transition."

Amongst the questions which anthropology has to deal with, that of the descent of man has been so elaborately treated, and at the same time popularized by Mr. Darwin, that it would be serving no useful purpose were I to allude to any of the arguments on which he has based his belief in the unbroken continuity of man's development from the lower forms of life. Nor is it necessary for one to discuss the question of the *monogenesis* or *polygenesis* of man. On this subject also Mr. Darwin has shown how unlikely it is that races so closely resembling each other, both physically and mentally, and interbreeding as they invariably do, should on the theory

of development have originated independently in different localities. Neither are we now, I think, in a position to doubt that civilization has been gradually and progressively developed, and that a very extended, though not by any means uniform, period of growth must have elapsed before we could arrive at the high state of culture which we now enjoy. The arguments of our sectional President, Sir John Lubbock, on this subject may, I think, be accepted generally as those of the best exponent of these views in our own time; such was the opinion, as we learn from various authorities, that was held by most of the ancient authors, and it tallies in all respects with the phenomena of progress now observable in the world around us, or which have been recorded in history. Indeed it almost appears probable that had it not been for certain dogmas inculcated in our youth, and from the influence of which in biasing our judgment it is difficult to disengage ourselves in after years, we should never for a moment have thought it possible that civilization could have arisen through any other causes than those by which we actually see it developing in our own times.

How far the first beings worthy of being called men may have possessed superior organic psychical powers to their predecessors, and whether the superior functions of the human mind were developed slowly or rapidly is a point on which it is more difficult to form an opinion. In contrasting the psychical differences between man and the lower animals, it is so invariably the practice to include, and indeed so impossible to avoid including, in our estimate of the human intellect all that conscious education and unconscious infantile culture has added to the powers of the mind, that unless we were able to try the experiment of the Egyptian king, and send children to be brought up with animals apart from all intercourse with the human race, we could not place ourselves in a position to compare truly the innate capacities of the two, or to form any just estimate of the difficulties which primæval man, even supposing him to have possessed mental powers equal to our own, must have encountered in the first stages of human culture. It has been shown by Prof. Huxley and others that there is really no cerebral barrier between men and animals; nor does it appear beyond the pale of possibility that a slight increase in the vividness or permanence of the impressions of external objects upon the mind over that possessed by the brutes, might, by marking more clearly the sequence of events, be sufficient to initiate that faculty for improvement which is the special characteristic of man.

Be that as it may, there is, I believe, nothing in the constitution of our own minds which can lead us to doubt that the progress of our first parents must have been extremely slow, or that the slight improvement observable in the implements of the neolithic over those of the palæolithic age did actually correspond to the continuous progression of human culture during enormous periods of time.

Now, if it is true that during the countless ages included in the palæolithic and neolithic periods (which we know to have been marked by great geological changes, by the union and separation of great continents, by great changes of climate, and by the migration of various classes of fauna into distant parts of the earth) the progress of mankind was as slow and gradual as we are warranted in supposing it to have been by the relics which have been left us, considering how short the period of history during which the rapid development of civilization has taken place is in comparison with the long periods of time of which we have been speaking, and that progress is always advancing at a rapidly increasing ratio, we need find no difficulty in supposing that where savages are now found in the employment of implements corresponding to those of the neolithic age, they present us with fairly correct pictures of neolithic culture, being really in point of time only a little behind us in the race of improvement. It is reasonable also to suppose that the use of such tools by savages, and the culture associated with them, was also, like that of our neolithic parents, inherited from lower conditions of life, and that, being slow and continuous, it was sufficiently stable to enable us to trace connexions between people in the same stage now widely separated, and between them and our own neolithic ancestors.

The most remarkable analogies are in reality found to exist between races in the same condition of progress; and it is to the study of these analogies, with the view of ascertaining their causes and histories, that the attention of anthropologists has

of late been especially drawn; and on this subject I propose to make a few observations.

There are two ways in which it has been attempted to account for these analogous coincidences: one by the hypothesis of inheritance, to which I have already referred; the other by the view of the independent origin of culture in distant centres, assimilated in consequence of the similitude of the conditions under which it arose. It is said that the wants of man being identical, and the means of supplying those wants by external nature being alike, like causes would produce like effects in many cases. There can be little doubt that many remarkable analogies have arisen in this manner, especially amongst the very variable myths, customs, religions, and even languages of savage races, and that it would be dangerous to assume connexion to have existed except in cases where a continuous distribution of like arts can be traced. On the other hand, we should commit a grave error if we were to assume the hypothesis of independent origin, because no connexion is found to exist at the present time; for we are as yet almost entirely ignorant of the archæology of savage and barbarous races. It is but fifteen years since we began to study the prehistoric archæology of our own race, which has already carried us so far on the road towards connecting us with savages; and can we say what further connexions may be brought to light when the river-drifts of such rivers as the Niger or the Amazons come to be studied? Nor can it fairly be said that the wants of mankind are alike in all cases; for if we adopt the principle of evolution, it is evident that the wants of man must have varied in each successive stage of progress, diminished culture being associated with reduced wants, thus carrying us back to a condition of man in which, being analogous to the brutes, he could scarcely be said to have any wants at all of an intellectual or progressive character.

It would be an error to apply either of these principles exclusively to the interpretation of the phenomena of civilization. In considering the origin of species, we are under the necessity of allying ourselves either on the side of the *monogenists* or that of the *polygenists*; but in speaking of the origin of culture, both principles may be, and undoubtedly are, applicable. There is, in fact, no royal road to knowledge on this subject by the application of general principles; the history of each art, custom, or institution must be diligently worked out by itself, availing ourselves of the clue afforded by race as only the most probable channel of communication and development. We may be certain, however, that in all cases culture was continuously and slowly developed. Wherever we find an art or institution in an advanced or a conventionalized state, we may be certain that it did not originate and was not invented in that condition, but was the result of slow growth; and if the evidence of such growth is wanting in the locality, or amongst the people with whom it exists, it is rational to look for it elsewhere. Where, on the other hand, the arts are in a low stage of development, closely allied to each other in their objects, forms, or appliances, and largely dependent on the unaltered productions of nature, we may assume that they are indigenous.

There is but one existing race the habits of which are sufficiently well known, which can be said to present in any great degree the characteristics of a primæval people, and that is the Australians. As I have elsewhere noticed, all the weapons and tools of the Australians, whatever the uses to which they are applied, are closely allied to each other in form. The spear, the club, the malga, the boomerang, and the heileman, or rudimentary shield, all pass into each other by subvarieties and connecting links, and all consist of the but slightly modified natural forms of the stems of trees and other natural productions. The Australian in his arts corresponds the most closely of any people now living to those of the palæolithic age. His stone axe is sometimes held in the hand when used, and, like the palæolithic man, he has not yet conceived the idea of boring a hole through it for the insertion of a handle. In some cases he cannot without instruction even understand the use of such a hole when he sees it in the axes of European manufacture. A most remarkable instance of this was brought to my notice not long ago by Mr. Grimaldi, who found on the site of a deserted native camping-ground a European axe having a hole for the handle, which the natives, unable to conceive the use of this part, had filled up with gum, and hafted by means of a withy bent round the outside of the hole, in accordance with their traditional custom. Through the kindness of the owner, I

have here exhibited a drawing of this most instructive specimen of the primæval arts of the Australians. In the temporary museum established here during the meeting of the Association, you will see a case containing knives of stone, glass, and iron, all of exactly the same form, and hafted, if one may use such a term for the attempt to form a handle, precisely in the same manner, showing with what tenacity these people retain their ancient forms, even after they have been supplied with European materials.

Now it has been shown in some cases; and here I especially refer to the account lately published by Mrs. Millet, of the Native School established, under conditions only partially favourable to its success, in the interior of Western Australia*. The Australians are found in some cases to be not only capable, but even quick in receiving instruction. It is evident, therefore, that we should be wrong if we were to attribute the extraordinary retardation of culture on the Australian continent to racial incapacity *alone*; racial incapacity is *one* item, but *not* the only item to be considered in studying the development of culture.

The earliest inhabitants of the globe, as they spread themselves over the earth, would carry with them the rudiments of culture which they possessed, and we should naturally expect to find that the most primitive arts were, in the first instance, the most widely disseminated. Amongst the primæval weapons of the Australians I have traced the boomerang and the rudimentary parrying shield (which latter is especially a primitive implement) to the Dravidian races of the Indian peninsula and to the ancient Egyptians; and although this is not a circumstance to be relied upon by itself, it is worthy of careful attention in connexion with the circumstance that these races have all been traced by Prof. Huxley to the Australoid stock, and that a connexion between the Australian and Dravidian languages has been stated to exist by Mr. Morris, the Rev. R. Caldwell, Dr. Bleek, and others†. And here I must ask for one moment to repeat the reply which I have elsewhere given to the objection which has been made to my including these weapons under the same class, viz. "that the Dravidian boomerang does not return like the Australian weapon." The return flight is not a matter of such primary importance as to constitute a generic difference, if I may use the expression: the utility of the return flight has been greatly exaggerated; it is owing simply to the comparative thinness and lightness of the Australian weapon. All who have witnessed its employment by the natives concur in saying that it has a random range in its return flight. Any one who will take the trouble to practise with the different forms of this weapon will perceive that the essential principle of the boomerang (call it by whatever name you please) consists in its bent and flat form, by means of which it can be thrown with a rotatory movement, thereby increasing the *range and flatness of the trajectory*. I have practised with the boomerangs of different nations. I made a *facsimile* of the Egyptian boomerang in the British Museum, and practised with it for some time upon Wormwood Scrubs, and I found that in time I could increase the range from fifty to one hundred paces, which is much further than I could throw an ordinary stick of the same size with accuracy. I also succeeded in at last obtaining a return flight, so that the weapon, after flying seventy paces forward, returned to within seven paces of the position in which I was standing. This settles the question of the identity of the Egyptian boomerang; in fact it flies better than many Australian boomerangs; for they vary considerably in size, weight, and form, and many will not return when thrown. The efficacy of the boomerang consists entirely in the *rotation*, by means of which it sails up to a bird upon the wing and knocks it down with its rotating arms; very few of them have any twist in their construction. The stories about hitting an object with accuracy behind the thrower are nursery tales; but a boomerang when thrown over a river or swamp will return and be saved. In tracing the connexion between the arts of a people it is as necessary to study the principles of construction, as in tracing the connexion of languages or any other of the productions of human intellect. To deny the affinity of the Australian and Dravidian boomerang on account of the absence of a return flight would be the same as denying the affinity of two languages whose grammatical construction was the same because of their differing materially in their vocabularies.

* Australian Parsonage, or the Settler and the Savage, by Mrs. E Millet, chap. vii.

† Journal of the Anthropological Institute, No. 1. vol. i., July 1871.

Implements characteristic of the neolithic stage of culture have been found in all parts of the world, and the identity of their forms in regions remote from one another has attracted the notice of archæologists. By degrees some of the most primitive weapons would be superseded by others, and the improved forms would be rapidly disseminated. Community of goods, which is characteristic of a primitive state of society, would be a means of disseminating these improvements far more rapidly than afterwards, when the idea of personal property had been introduced, and before trade had been established. It has been found that in Western Australia, where no individual is able long to retain any thing as his own, and where members of another tribe are supposed to have a special claim on the possessions of an individual, this custom has been the means of conveying articles of European manufacture far inland into districts where the white man is unknown. We have also proof, in the migration of the Malays into Madagascar and the spread of the Polynesian race over the Pacific Ocean, that oceanic boundaries are not sufficient to prevent intercommunication between distant countries, and that intercourse between people in a comparatively low state of culture must frequently have taken place in prehistoric times. The earliest improvements would thus in time become the most widely disseminated, and therefore the most difficult to trace by their distribution at the present time.

Amongst the earliest improvements upon the primitive arts of man would be the substitution of the throwing-stick by the bow as a means of accelerating the flight and force of the javelin. So decided an advance in the employment of missile force would lead to the discontinuance of the throwing-stick for ordinary purposes wherever the bow was introduced. The throwing-stick is now found only in distant and unconnected regions, viz. in Australia, amongst the Esquimaux and the Purus Purus Indians of South America; and it has been assumed, on account of the isolated positions in which it is found, that it must be indigenous. On the other hand, the use of the bow is almost universal; and it has equally been assumed, on account of its world-wide distribution, that it must be indigenous in different localities, and not derived from a common centre. Geographical distribution, however, although affording the best evidence obtainable, cannot be relied upon with certainty in the case of so early an invention as the bow appears to have been. I cannot concur in thinking that we have any sure evidence that the bow originated in different places; on the contrary, what evidence we have appears to me to be of a contrary tendency.

In tropical and temperate regions the elastic properties of wood and its applicability to the purposes of offence would force itself upon the notice of the aboriginal man as he pushed his way through the underwood of the primæval forest. He would perceive that by tying his lance to the end of an elastic stem, and by a simple contrivance for retaining it in a bent position until the proper time arrived for releasing the spring, it might be made to pierce other animals as they passed through the wood; hence the spring-lance or trap, which we find widely distributed in parts of Africa and Southern Asia, and which in later years has been carried by the negroes into South America. By degrees he would see that, with the addition of a string, the trap might be made to project the lance with great force and accuracy; and the power thus afforded of wounding a wild animal or an enemy at a distance would at once commend it to his adoption. Where suitable spring wood existed, the construction of the bow was simple enough; but when the use of this weapon penetrated into northern climes, where an arctic flora did not supply wood of sufficient elasticity for the purpose, it would become necessary to supplement the stiff pine-wood or bone by some suitable material. It would be found that the sinews of animals fastened along the back would supply the elasticity that was wanting. By this means he would be led to the use of the composite bow, which is the bow peculiar to the northern hemisphere. A comparison of the modern Persian composite bow with those figured on the Greek vases proves that this was the form of bow used by the Scythians and others in ancient times. In Lapland we find the same form. It was carried by the northern immigrants into India, but it is not indigenous in that country. By the Tartars it was introduced into China. We find it also on the east coast of Siberia. Across Behring Strait it reappears amongst the Esquimaux in its most primitive form; but the returns at

the ends prove it to be unmistakably the same weapon as the Tartar bow. It is found also in British Columbia, and down the west coast of America as far as California.

Here, then, we have the continuous distribution across two entire continents of a particular class of bow, of a more complex form than the southern bow, and one, therefore, which is not likely to have been adopted except by a people to whom the simpler but equally effective form was known, but who did not possess the materials necessary for its construction. It would not, perhaps, require a very wide stretch of imagination to suppose that this class of bow may have originated at a time when an arctic flora similar to that existing amongst the Esquimaux may have been more widely distributed in the northern hemisphere than at present, and its advantages for employment on horseback would be a cause for retaining it. Be that as it may, we have proof that this composite bow is of great antiquity, and that it has been carried by intruding races into distant countries. May not the use of the simpler and earlier bow have been spread in the same manner? It may have been, but we cannot say that it was. The resemblance between the South-American bows and arrows and those from New Guinea is so close that it is sometimes difficult to distinguish them. Even the ornamentation upon them is much alike; and it is well known to all Prehistorians that the arrow-heads found on the American continent present all the four types of leaf-shaped, lozenge-shaped, triangular, and barbed, that are found in Europe.

As by degrees the use of the bow spread over the world, that of the throwing-stick would tend to disappear. We have some grounds for supposing that the latter instrument was formerly in use in the Pelew Islands; and Mr. Franks has found it amongst some Mexican relics probably preserved in a tomb. May it not also have existed formerly in other localities where it has not been preserved in tombs, and where no trace of it now exists? If this were the case, where should we now expect to find it retained? In such localities as the Arctic seas, where lack of suitable materials still renders the construction of the bow a work of great difficulty, as is shown by the manner in which several pieces of hard bone are sometimes fastened together to form one, or in Australia, where the knowledge of the use of the bow has never penetrated.

Closely connected with the bow, the harpoon may be instanced as an example of early origin and wide distribution. The harpoon is found in some of the French caves, amongst the earliest bone relics of human workmanship that have been brought to light. Its present distribution is almost universal, being found in Australia, North and South Africa, North and South America, and in all regions where its use has not been superseded by more suitable contrivances.

In proportion as our investigations are carried into the higher phases of civilization, we find our areas of distribution more limited, and of more and more value to us is tracing the continuity of culture; and when we come to the distribution of the metallurgic arts, we find them defined by marked geographical boundaries which are not the boundaries of the great primæval races of mankind.

If we draw a line across the globe from Behring Strait in a south-westerly direction through Wallace's line, leaving Australia on the east, and take for our period the date of the first discovery of America, we shall find that (putting aside the metallurgic culture of Mexico and Peru, which, it may be observed, is grouped round a single centre) this line separates the area of stone culture on the east from the area of metallurgic culture on the west; but it passes straight through the primæval racial boundaries. Turning to the ethnological map of the world, we find in the southern hemisphere the black races of man occupying a continuous area, extending from Australia on the east to Africa on the west; of these, the eastern portion are in the area of stone culture, whilst the western have long become acquainted with the use of metals. Or if we divide these black races, as Prof. Huxley has divided them, into Australoid and Negroid stocks, including amongst the latter the Negritos, we find equally that with each of these primæval stocks the eastern half are in the stone area, while the western are acquainted with the use of metals. In the northern hemisphere we also find the great Mongoloid stock, which includes the inhabitants of northern and eastern Asia and the two continents of America, divided by our line in two portions, of which the eastern are in the stone area, while the

western have made considerable advance in metallurgic culture. Here, then, we see that the distribution of the metallurgic art had, at the time we speak of, spread over three continents, and been brought to a stand by great oceanic boundaries, beyond which it had not penetrated, unless, indeed, it had been carried by some vessel to the coast of Peru.

If we now take what we may call the metallurgic area more in detail, and endeavour to trace the distribution of the implements of the bronze period, we find that the same class of weapons and tools extends over a continuous area, including the whole of the northern, western, and central parts of Europe, as far as Siberia on the east; these implements, including palstaves, leaf-shaped swords, and socket celts, with the moulds for casting them, are of a character to prove that the diffusion of the bronze culture throughout this area must have been connected and continuous. In Egypt, Assyria, India, and China we have also bronze; but the forms of the implements do not, as a rule, correspond to those of the area above mentioned: our knowledge of the bronze weapons of India and China is, however, extremely limited as yet. I have elsewhere given my reasons for believing that the knowledge of the use of iron in Africa must have been derived from a common centre; not only is the mode of working it the same throughout that continent and in India, but the forms of the weapons fabricated in this metal, and especially the corrugated blades, are the same in every part, and appear to have been copied and retained through habit wherever the use of iron has penetrated. I have lately traced this peculiar form of blade in several parts of the Indian peninsula and Burmah, and I have no doubt it will eventually be found further to the north, so as to connect the area of its distribution continuously with those of the same identical construction that are found in the Saxon and Frankish graves.

The distribution of megalithic monuments extends in a continuous belt, as has been repeatedly shown, from western Europe to eastern and southern India; and however little disposed some of us may be to agree with Mr. Fergusson as to the age to which he refers these monuments, for my part I concur with him in thinking that their distribution denotes intercommunication on the part of the constructors of them. The art of enamelling, which was known to the Celts and Romans, as well as to the Chinese, will, I have no doubt, be shown hereafter to have been derived from the east, or at least to have spread from a single source. It is worthy of notice that the present distribution of filigree work, which is closely connected with enamelling, and which may be regarded as a survival of that antique art, is now found to be practised in a continuous belt from China on the east to Spain on the west; and with the exception of some rough Scandinavian work of the same character, it is not, I believe, found out of this channel. This, indeed, appears to have been the high road of communication in non-historic times, and indicates the route through which many of the so-called early European discoveries may have been derived.

I have thus briefly alluded to the distribution of some of the arts associated with early culture, with the view of showing that as our knowledge increases we may expect to be able to trace many connexions that we are now ignorant of, and that we should be careful how we too readily assume, in accordance with the theory which appears popular among anthropologists at the present time, that coincidences in the culture of people in distant regions must invariably have originated independently because no evidence of communication is observable at the present time. Owing, perhaps, to a praiseworthy desire to refute the arguments of Archbishop Whately and others, who have erroneously, as I think, assumed that because no race of existing savages has been known to elevate itself in the scale of civilization, therefore the first steps in culture must have resulted from supernatural revelation, we have now had a run upon the theory of what may be called the spontaneous generation of culture; and the pages of travel have been ransacked to find examples of independent origin and progress in the arts and customs of savage tribes. Owing to this cause, we have, I think, lost sight in a great measure of the important fact which history reveals to us, that, account for it as we may (and it is one of the great problems of Anthropology to account for it if we can), the civilization of the world has always advanced by means of a leading shoot; and though constantly shifting its area, it has within historic times invariably grouped itself round a single centre,

from which the arts have been disseminated into distant lands or handed down to posterity. In all cases a continuous development must be traced before the problem of origin can be considered solved; the development may have been slow or it may have been rapid, but the sequence of ideas must have been continuous, and until that sequence is established our knowledge is at fault. As with the distribution of plants, certain soils are favourable to the growth of certain plants, but we do not on that account assume them to be spontaneous offspring of the soil, so certain arts and phases of culture may flourish among certain races or under certain conditions of life. But it is as certain that each art, custom, and institution had its history of natural growth; it is that each seed which sprouts in the soil once fell from a parent stem. The human intellect is the soil in which the arts and sciences may be said to grow; and this is the only condition of things compatible with the existence of minds capable of adapting external nature, but possessing no power of originality.

If I am right in supposing that it is one of the primary objects of Anthropological Science to trace out the history and sources of human culture, a consideration of the relative value of the various classes of evidence on which we rely for this purpose will be admitted to be a question of no slight importance in connexion with our subject. We must distinguish between those branches of study which we are apt to look upon as intrinsically the highest, and on that account the most attractive, and those which are of most value as evidence of man in a low condition of culture. To the religions, myths, institutions, and language of a people we are naturally drawn, as affording the best indications of their mental endowments; but it is evident that these carry us no further back in time than the historic period; and however necessary to be studied as branches of our science, they fail to afford us any direct evidence of those vast ages during which our species appears to have gradually taken upon itself the characteristics of humanity: every age has, however, left us the relics of its material arts, which, when studied comprehensively in connexion with the geological record, may be taken as evidence of mental development from the earliest period of time. Nor is it in point of time alone, but also by reason of their stability, that the material arts afford us the surest evidence on which to reconstruct our social edifice. The tendency to constant variation within narrow limits is a psychical characteristic of the uncultivated man; but the material arts are not subject to those comparatively abrupt changes to which, prior to the introduction of writing, all branches of culture are liable which are dependent for their transmissions on the memory, and which are communicated by word of mouth.

Few who have read the works of Prof. Max Muller or Mr. Farrar can fail to be struck with the value of the evidence afforded by language, so far as it goes, but, on the other hand, with the very short distance to which it carries us back in investigating the origin of speech; nor is this surprising when it is considered how constant must have been the changes to which language was subject in prehistoric times. Amongst the one hundred islands occupied by the Melanesian race, the Bishop of Wellington informs us there are no less than two hundred languages, differing from each other as much as Dutch and German; and this diversity of languages and dialects is confirmed by Mr. Turner, in his account of his nineteen years' residence in Polynesia. Amongst the Penons, or savage tribes of Cambodia, we read of the great number of dialects spoken by tribes whose manners and customs are the same. Amongst the Musgu of Central Africa, Barth tells us that, owing to the absence of friendly intercourse between the several tribes and families, such a number of dialects had sprung up as to render communication between them difficult. Upon the river Amazon Mr. Bates mentions that in a single canoe he found several individuals speaking languages so different as to be unintelligible to the others. In a state of culture in which such diversity of tongues existed, what could have been the chance of preserving unchanged the myths, religions, and all those manifestations of intellect which are dependent on tradition? It has, in fact, been found, by those most competent to judge, that they are not reliable in any great degree as evidence of connexion between distant tribes and races in an early condition of culture. Even in cases in which time and diversity of dialect, as causes change, have been eliminated, the experience of everyday life proves how little reliance is to be placed in the verbal transmission of ideas. In studying Gallic traditions, Mr. Campbell, of Islay, who has collected a larger number of Gallic stories than

any man living, informs me that although the general plot of a story, like the grammatical construction of a language, may with doubt and difficulty be traced through many variations into distant countries, the details in all that relates to names of the heroes, costumes, and implements, and all the material events connected with the stories are subject to such radical changes as to render them totally untrustworthy in point of date and sequence. Mr. Tylor also, in his interesting and valuable work on primitive culture, has stated his inability, by means of myths and religions, to trace in the majority of cases the connexion between early races; and this circumstance, fairly and rationally as he has placed it before us in all his writings, has, I venture to think, led many who rely mainly on this class of evidence to incline too strongly towards the hypothesis of independent origin (more so at least than I should be disposed to do), and to make insufficient allowance for the rapidly recurring changes produced by the imperfect transmission of ideas, through the operation of which all trace of the channels of communication would be rapidly obliterated, and those myths which, from being best suited to the mental condition of the people, had survived in distant countries would present the appearance of spontaneous and independent origin. In all this class of anthropological evidence Mr. Tylor has shown that the invention of writing and other concomitants of improved culture have been the means of introducing an element of stability and permanence, so that we are presented with the phenomena of progress in the direction of unity and simplicity as opposed to diversity and complexity. On the other hand, the language of the arts may be said to have been a written language from the time of the first appearance of man upon the earth; less liable to variation in transmission, the links of connexion between lower and higher forms have been preserved and handed down to us from the remotest period of time, and by testifying to the comparatively steady and continuous development which has taken place, encourage us to hope that by diligently prosecuting our studies into this department of anthropology, every relic of prehistoric ages may eventually be made to mark its own place in sequence, if not in time.

The greater stability of the material arts as compared with the fluctuations in the language of a people in a state of primeval savagery is well shown by a consideration of the weapons of the Australians and the names by which they are known in the several parts of that continent. As I have already mentioned, these people, from the simplicity of their arts, afford us the only living examples of what we may presume to have been the characteristics of a primitive people. Their weapons, respecting the distribution of which we have more accurate information than we have of their vocabularies, are the same throughout the continent; the shield, the throwing-stick, the spear, the boomerang, and their other weapons differ only in being thicker, broader, flatter, or longer in different localities; but whether seen on the east or the west coast each of these classes of weapons is easily recognized by its form and uses. On the other hand, amongst the innumerable languages and dialects spoken by these people, it would appear that almost every tribe has a different name for the same weapon. The narrow parrying-shield, which consists of a piece of wood with a place for the hand in the centre, in South Australia goes by the name of Heileman, in other parts it is known under the name of Mulabakka, in Victoria it is Turnmung, and on the west coast we have Murukanye and Tamarang for the same implement very slightly modified in size and form. Referring to the comparative table of Australian languages compiled by the Rev. George Taplin, in the first Number of the 'Journal of the Anthropological Institute,' we find the throwing-stick, which on the Murray River is known by the name of Yova, on the Lower Darling is Yarrum, in New South Wales it is Wommurrur, in Victoria Karrick, on Lake Alexandrina Taralye, amongst the Adelaide tribes, South Australia, it is Midla, in other parts of South Australia it is called Ngeweangko, and in King George's Sound Miro. None of the weapons show less variety of form than the boomerang; on the Murray River this is known by the name of Wanya, on the Lower Darling Yarrumba, on the North Darling Mulla-Murraie, on Lake Pando Wadna, on the Liverpool Plains Burran, in Victoria Kertom, on Lake Alexandrina Panketye, and in King George's Sound Kyli. Between the majority of these names it will be seen that it is impossible to trace the faintest resemblance of sound. Yet no one, it is presumed, would be so

irrational as to suppose that so peculiar a weapon as the boomerang, for example, could have been invented independently in as many different localities as there are different names for it; nor is it reasonable to suppose that such extremely simple weapons as those in use by the Australians should have spread from a common centre, subsequently to the establishment of the various languages as they are now spoken. The weapons of the Australian, as I have shown in my paper on Primitive Warfare, published in the 'Journal of the Royal United Service Institution,' are all traceable, like the languages, to primitive forms, which are the natural forms of stumps and stems of trees; like the languages they have also varied and diverged; but whilst the names for them have changed so completely as to present no signs whatever of connexion in the different tribes, the weapons themselves have varied so slightly as to be recognized at a glance in all parts of the Continent. Even in modern times, since the introduction of writing has given permanence to the languages and ideas of the people amongst whom it has been introduced, we find instances of the comparative stability of the material emblems and forms of things in the retention of pagan emblems in our own religions and those of other countries, and notably the employment of fire and water in our religious ceremonies, which have survived with so much vitality as to be living sources of controversy amongst parties, one and all of whom would utterly repudiate the ideas with which these emblems were associated at their birth.

If, then, it is evident that much of the history of our prehistoric ancestors has been for ever lost to us, we may console ourselves with the reflection that in their tools and weapons and other relics of their material arts the most reliable source of evidence as to their intellectual condition has continued to our time. As to the myths, religions, superstitions, and languages with which they were associated, we may content ourselves by devoutly thanking Providence that they have not been preserved. As it is, anthropological studies are said to have their fair share in the creation of lunatics: and we can easily believe that no sane intellect would have survived the attempt to unravel such a complex and tangled web of difficulty as the study of these subjects would have presented to our minds.

Two other examples, with your permission, I will give for the purpose of illustrating the principle of variation and continuity as applied to the customs and arts of savage races, and the relative superiority of material evidence in tracing the changes effected by these means. The customs associated with the practice of human sacrifice amongst the Konds of India have received prominent notice of late years, owing to the steps which have been taken by the Government to put them down. From the reports presented to the Government of India by various officers, we learn that these customs vary considerably in minor points in different localities. Amongst those who have written on the ethnology of India, there is no one from whose accurate and scientific observation of the habits of the aborigines we have derived more valuable information than Sir Walter Elliot. From him we learn that similar customs prevail in every village in Southern India. The village customs, however, differ from the Kond rites in this important particular, which we can easily understand is the reason why the resemblance between them has never been noticed by former writers namely, that the practice of human sacrifice has been abandoned, and a buffalo is substituted for a human victim; in the mode of sacrificing and disposing of the flesh and other matters connected with the rites, we see that these village customs are in reality the modern representations of the more ancient Kond sacrifices, and that whilst an immense step has been made in the civilization of the people by the abandonment of the barbarous practice of human sacrifice, the parallel to which is probably seen in the account of Abraham's sacrifice in the Old Testament, the continuity has been kept up by the preservation of some of the minor customs which are associated with the more ancient rites. Now Sir Walter Elliot tells us that these modified village sacrifices, like the older human sacrifices, vary in the details in every village of Southern India. I need hardly say how much the value and accuracy of these studies would be promoted if we could obtain detailed accounts of the varieties of these customs as they are now practised in the several villages, with the causes of variation in each case; we should by this means obtain an insight into the process of development of these customs as they are now seen

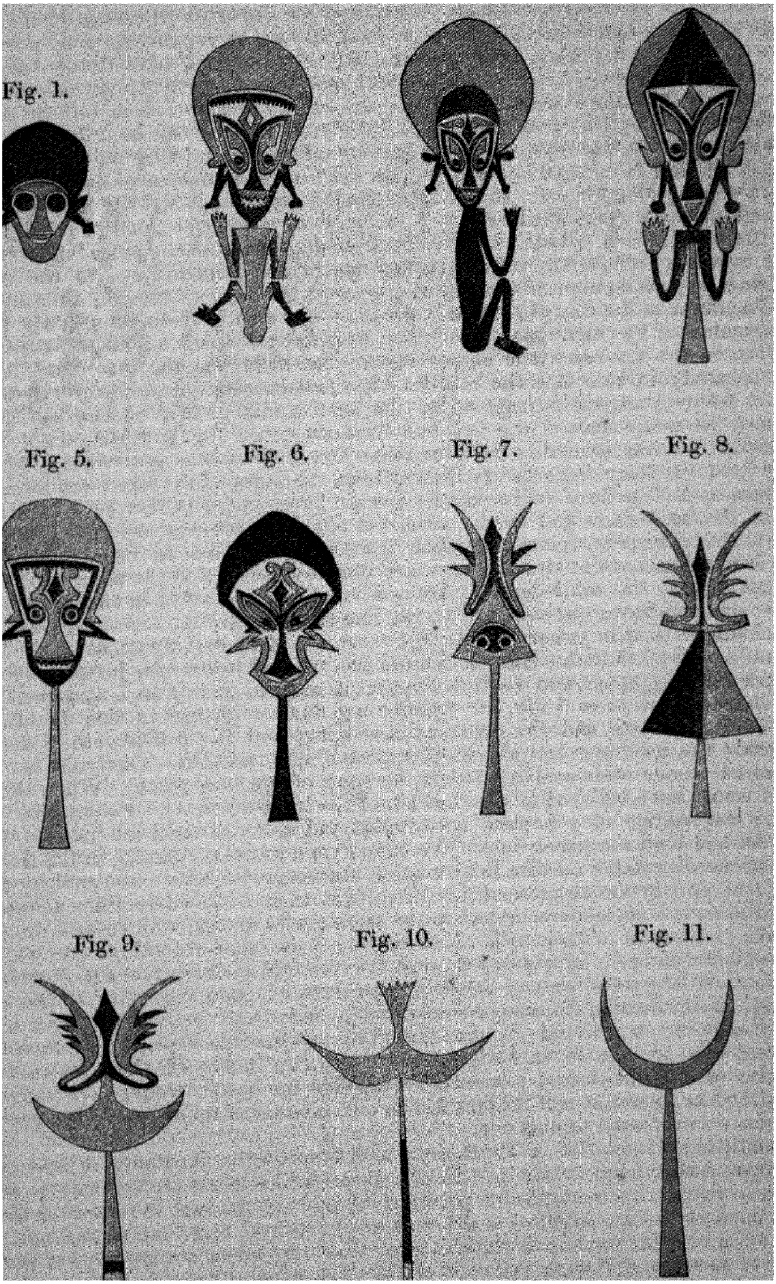
actually on the move at the present time. Hereafter, in all probability, as they continue to vary by the omission of some portions of the ceremonies and the substitution of others, some one village, more advanced and more powerful than its neighbours, in the natural course of things will obtain the ascendency, and will impose its peculiar and greatly modified version of these rites upon the neighbouring villages, by which means the links of connexion will be completely lost. I believe the time is at hand when we shall make as much ado over a variety of custom or form of implement as naturalists now do over a new moth or a beetle, and then anthropology will become a *science*.

My next illustration is taken from the ornamental paddles of the New-Irelanders, one of the Papuan group of islands adjoining the one in which Bishop Patteson was lately murdered. In none of the productions of savage art is the tendency to continued variation within narrow limits more strongly shown than in these ornamental patterns. Whilst the form of a club or a paddle appears to remain unchanged for many generations, the form of ornament upon it will be subject to variations, which, however, are not the less found to be continuous and connected when a sufficient number of specimens are collected, so as to enable their history to be traced. The continuous looped coil and its varieties, and its ultimate development into the continuous fret pattern, may be traced in its migrations through distant regions. Sometimes a particular variety of these patterns will establish itself in a tribe or a nation; and whilst subject to an infinity of subvarieties, it will be found to be repeated over and over again in all the weapons and implements belonging to this tribe. The ornamentation employed by the tribes on the N.W. coast of America consists entirely of the representation of a bird's head, the eyes and beak of which have been subject to such variations in copying as completely to have lost all trace of the original design. The New-Irelanders ornament their paddles with the figure of a man painted in red and black, carved upon the face of the blade. Fig. 2 is a good example of this conventionalized mode of representing the human figure in full; fig. 11 is another ornament upon the paddle of the same people; and between these two figures it would not at first sight appear possible that any connexion could be traced.

Ingenious theories might, perhaps, be based upon the occurrence of such a figure as that represented in fig. 11 amongst the Papuan Islands; it might be assumed that Mahomedanism had once penetrated that region, and they had adopted the symbol of the crescent, or the advocates of spontaneity would find no difficulty in at once assuming that they had copied the new moon. No one who had not by previous experience been impressed with the continuity pervading all savage ornamentation would *dream* of connecting two such widely different forms as those represented in these two figures. Those, however, who are familiar with the pictographic changes which marked the origin of the Phœnician and Scandinavian alphabets, or who have studied Mr. Evans's work on Ancient British Coins, or the researches of Mr. Edward Thomas into the Coins of India, will be prepared for the marvellous transformations to which human and other forms are subjected when they are copied and recopied by the inaccurate and uninstructed eyes of savage imitators. They will remember how the chariot and horses on the Greek coins of Philip of Macedon, in the hands of the Gaulish and British artists, gradually lost, first the body of the chariot, then the body of the charioteer—how the wheels of the chariot became mixed up with the body of the horse, and the head of the driver appeared floating like a cherubim over the horse's ears—and how, on the obverse of the coin, the nose and features of the head gradually disappeared, until nothing but the wreath converted into a cruciform ornament remained to connect it with the original figure of the Greek king. Impressed with the idea of the physical identity of people in the same condition of culture, I determined to collect New-Ireland paddles, and see whether a connexion would be found to exist between the peculiar patterns with which they are ornamented. The result is the series now before you, which I have obtained at different times during the last seven years as they turned up in curiosity-shops or were brought over by travellers from the South Seas; and it must be understood that these particular specimens are not selected to serve my purpose. I have here given the whole of the collection of patterns which have fallen into my hands. Let us see how far they serve to sup-

Ornamentation of New-Ireland Paddles, showing the Transition of Form.

Fig. 2. Fig. 3. Fig. 4.



port our views as to variation and continuity now that they are put together. Fig. 1, it will at once be seen, represents, both on the handle and on the face of the blade, the head of a Papuan; the large black mass on the head, like a grenadier-cap, is the Papuan head-dress peculiar to these parts; the ears are elongated according to the custom of these people, and pierced with an ear-ornament; the eyes are round black dots, the nose a triangular red mark, and the same colour is spread over the forehead. Fig. 2 represents the full figure of a Papuan sitting; the ears are drawn down towards the hands, the head is somewhat conventionalized, the line of the nose is carried round the eyes in a scroll, and there is a lozenge-shaped pattern on the forehead. Fig. 3 is nearly the same figure represented as sitting sideways, simply by lopping off an arm and a leg on one side. In fig. 4 we have two arms, but no legs, and the head continues much the same as in the two preceding figures. In fig. 5 the whole body is gone, and the scroll-pattern round the eyes is modified in form. In fig. 6 we see a great change in the form of the head, which is much more conventionalized than in the preceding figures; the eyes are reduced to small dots, and are rendered subordinate to the scroll formed by prolongation of the line of the nose; the sides of the face are concave, and conform to the line of the nose; the chin and mouth are enlarged; the head is surmounted by the Papuan head-dress, as before; there is a lozenge-pattern, as before, on the forehead; the elongated ears are there, but the ear-ornament has disappeared; in this face the nose has become the prominent feature, and the other features are subordinate to it. In fig. 7 a still greater change has taken place; the greater part of the face and head are gone. In the last figure we saw that the nose was becoming the prominent feature, here it is nearly the only feature left; the elongated ears are drawn down the sides of the nose; the lozenge-pattern on the forehead still remains; but the lines, which in the previous figures led to the head-dress and to the scroll-pattern, have been turned into a kind of leaf-shaped ornament, resembling what appears to have been the upper lobe of the ear in the previous figures; the eyes are brought down on to the nose. In fig. 8 we have nearly the same figure as the last: the nose is divided in two; the elongated ears are drawn out square with the line of the nose; the lozenge-pattern on the forehead is still preserved. In fig. 9 we see the same figure as in the last example, except that the triangular nose has merged into what, judging by the previous figures, appears to be the chin, or it may be merely an enlargement of the base of the nose. Fig. 10 represents a further change in this direction; the lozenge-pattern and the ears are now gone, and the leaf-pattern is much reduced; the nose also has almost disappeared into the chin. Lastly, in fig. 11, we come to our Mahomedan emblem, or copy of the new moon. What is it? Who would have believed it was the chin of the human figure? Yet so it is. It is the last vestige of a human face, copied and recopied until all trace of the original had been completely lost. We have here a complete parallel to the transformations observable on the British coins, showing with what close analogy the minds of men in the same condition of culture, though of widely different races, obey the same laws and are subject to the same causes of variation and continuity in the development of their arts. Now, if we suppose the connecting-links which are exhibited in these figures to represent the connecting-links of myths, customs, religions, or languages, or any other productions of human ingenuity which are not embodied in material forms or committed to writting, it is evident they would have been lost; they would not have turned up in curiosity-shops, or been brought together side by side in an instructive series. The theory of the spontaneous adoption of crescent-shaped patterns, by copying the moon, would have become established as an almost self-evident fact in our minds, and no one could for a moment have seen reason to doubt it.

In omitting all mention of Psychology and Comparative Anatomy, it must not be supposed that I am unmindful of the services which these studies may be expected to render to our science hereafter. Nor is it unimportant to remember that Anthropology has its practical and humanitarian aspect, and that, as our race is more often brought in contact with savages than any other, a knowledge of their habits and modes of thought may be of the utmost value to us in utilizing their labour, as well as in checking those inhuman practices from which they have but

too often suffered at our hands. These are branches of the subject into which I have no time to enter on the present occasion. I believe, however, that for some time to come prehistoric archæology, and the comparative study of the arts of races in different conditions of culture, must continue to hold a prominent place amongst the researches of anthropologists, not on account of the greater importance or interest attaching to the investigation of these subjects, but on account of the superior quality of the evidence which these studies afford.

The consideration of the value of evidence naturally leads us to the third part of my subject—namely, the mode of collecting it and of digesting it after it has been brought together; and as this is, I believe, the most defective part of our organization, or, to speak more properly, the part of our existing institutions in which our want of organization is most conspicuous, I had intended to have spoken at greater length on this subject; but as I have already trespassed upon your time so long, I am under the necessity of curtailing what I had to say on the subject of organization. If I am wrong, as I have heard it suggested by some anthropologists, in supposing that the greatest difficulties under which we labour are attributable to the absence of reliable evidence, and if we already possess as much information about savages and about prehistoric men as we require, and we have nothing to do but to read the books in our libraries, and write papers calculated to promote discussion and fill journals with interesting controversies and speculations—if, as I gravely heard it asserted not long ago at a public meeting, it would be a pity to explore Stonehenge for fear so remarkable a monument should be divested of that mystery which has always attached to it, owing to our entire ignorance as to its origin and uses, then to those who entertain such views the few remarks I shall venture to offer on this subject must appear not only superfluous but mischievous. But if, on the other hand, I am right in supposing that our existing evidence is lamentably deficient, and in many cases false—that it has been collected by travellers many of whom have had but little knowledge what to look for and observe—and if, this being the state of our knowledge, the evidence which we desire to obtain is now rapidly disappearing from the face of the earth (the Tasmanians have been swept away before we know any thing about them; the New-Zealanders and all the Polynesian-Islanders are fast changing their habits; and it is now difficult to find a North-American Indian in a state of unadulterated savagery; whilst at home our prehistoric monuments are broken up and ploughed down day by day in the construction of buildings and railroads), it is evident that a set of societies which provide no organization whatever for promoting exploration at home or abroad can only be regarded as fulfilling very imperfectly the functions which institutions established for the purpose of anthropological investigation might reasonably be expected to serve. Beyond the limits of this Association there is but one Society in this country which has the funds necessary for promoting explorations, and that is the Geographical Society. Every expedition which goes out under the auspices of that Society is necessarily brought in contact with the races inhabiting the districts which are explored; but it can hardly be expected that the Geographical Society should do as much as could be desired in the way of promoting anthropological investigation, as long as Anthropology and Ethnology are excluded from the functions of that Society. A Geographical Society should be regarded as the eyes and ears of an Anthropological Society abroad, in the same way that the Archæological Societies should fulfil the functions of eyes and ears directed to the past history of man, and the most intimate alliance ought to exist between them. A step in the right direction has lately been taken, at the suggestion of Mr. Clements Markham, by the establishment of a joint committee of the Geographical Society and Anthropological Institute, to draw up questions for travellers whom it is proposed to send to the Arctic seas; and this, it is to be hoped, will be the first step towards a more intimate alliance in the future. As to the Archæological Societies, whose name is legion, and the functions of which are necessarily anthropological in a great degree, they are as a rule the most impotent and unprogressive bodies, living from hand to mouth, with funds barely sufficient to maintain a secretary and to produce a small volume of Transactions annually; without the means of promoting exploration, they are dependent entirely upon the casual communications of members, the substance of which is sometimes

repeated over and over again in the different societies. These Archæological Societies and others (which I do not particularize, because I am anxious that my remarks should not appear to be directed pointedly to any one of them) collectively provide libraries in the proportion of four or five libraries to one or two students who habitually read the books in them. When museums form part of the establishments, they succeed in collecting a stray Chinese umbrella or two, and a stuffed monkey, or a few bronzed implements in a case. Each Society has separate apartments provided at great cost; these are empty at least six days a week, and usually thirteen days in the fortnight, during the short period in which the session is held. One of these societies is in the possession of a magnificent suite of apartments, which are provided at the Government expense, and furnished with rows of tables and benches and a splendid throne for the chairman, in which I have occasionally had the honour to sit. It is to be hoped that whenever the power of psychic force, or the influence of disembodied spirits in vivifying inanimate bodies, comes to be more generally established amongst anthropologists than it is at present, these chairs and tables may proceed to deliberate and rap out archæological communications to each other during the weary days and hours that the embodied spirits are absent. Whenever any undertaking of national interest has been set on foot, such as the Bill for the Preservation of Prehistoric Monuments, proposed by Sir John Lubbock, inviting the united interest of these societies to bring it forward, the first inquiry has been as to which of these societies has had the credit of having originated the measure; and if found to be tainted by the support of a rival society, it has been at once repudiated, or only adopted after its success has with great difficulty been secured by other means. If we inquire what useful purpose is served by these divisions of the metropolitan societies, we are told that one is a society, another is an association, and a third is an institute; and yet it does not appear that any one of these societies, associations, or institutes perform any special function which cannot equally well be served by the others. They constitute divisions of persons rather than divisions of subjects; instead of promoting division of labour, they serve only to promote repetition of labour; and so ill do any of them answer the expectations of those who devote themselves to the close study of any one branch of archæology or anthropology, that it has lately become necessary to establish an additional metropolitan society for promoting protohistoric archæology, under the title of the Society of Biblical Archæology, embracing subjects which fall mainly within the domain of anthropology. Much as I should feel disposed to condemn the multiplication of societies under existing circumstances, I cannot but think that by promoting the close study of a particular branch, the establishment of this Society is a step in the right direction; and I therefore trust that it may be found to flourish at the expense of those which appear to have no special function to perform. As a prehistoric archæologist, I can only add my humble testimony to that of others who think that this branch of anthropology is very unsatisfactorily dealt with by the metropolitan societies in which it is discussed. On a recent occasion, when speaking on this subject, I compared the position which prehistoric archæology now holds in the London societies to that of a poor relation. I might, perhaps, extend the simile further by saying that, like many poor relations, it is also the most agreeable relation, and though duly snubbed in accordance with the orthodox custom in like cases, its services will not be willingly dispensed with, as it furnishes sensational topics for not less than six societies in London at the present time. The discussions, however, are for the most part confined to the most rudimentary branches of the subject, and but little importance attached to details, because the principles are not understood. Quite recently this happy family has been increased by the birth of a fine child, under the title of an Historic Society; and I observe that, by way of specializing the functions of this Society, it commenced life with a paper on Prehistoric Man. But there are no signs of any limitation to this improvident childbearing; it is announced that a Psychological Society is confidently expected. No one would be more disposed than myself to welcome psychology as a special branch of study if this family of gutter-children is to go on increasing *ad libitum*; but it will be admitted that a Psychological Society of all others is liable to grow up scatterbrained if completely severed from the influence of its more experienced kinsfolk.

But I have said nothing as yet about the country cousins. If the heads of the families are such as I have endeavoured to describe them, what must the country cousins be? I have spoken of the gutter-children of the metropolis; but we must follow the gutters into the sewers before we can form a just estimate of the condition of the local societies; and yet I believe that with a very small amount of organization the local societies are capable of performing the most important functions in regard to at least one branch of our science. It is hardly necessary for me to observe that my remarks apply exclusively to the question of *organization*, and cannot for a moment be supposed to have any bearing on the abilities of the individual members, amongst whom are included many very able men; but we all know that the best army in the world may be rendered impotent through defective organization. The conditions under which local societies are established are incompatible with a very high standard of efficiency in any special department of science; owing to the very various qualifications of a small body of members, their proceedings must necessarily be miscellaneous; but they are usually supported by local interests, which may be of the utmost value, and are often indispensable in promoting the exploration of local prehistoric antiquities, and they only require the *prestige* derivable from a national organization to render them efficient in this respect. As it is, local societies have often reason to complain of the metropolitan societies, which draw some of the best correspondence from the counties and give but little in return.

I trust that I have made it apparent that anthropology in its various branches includes some of the most popular and widely disseminated scientific interest of the country, and that the loss of power is enormous; not only is there no means of organized exploration, but the information which is published is either repeated over and over again in the different societies, or it is so scattered as to be beyond the reach of the majority of the students. They labour also under the disadvantage of being supported chiefly by men of small means; for the well-to-do classes in this country do not, as a rule, take any interest in either scientific or anthropological investigations. During the past year a single American has done more in the way of anthropological exploration than the whole of the English societies, institutes, and associations together.

I will now briefly state my views as to the remedies for the evils of which I have spoken. I am averse to the principle of amalgamation: the most active members are not always the most enlightened; narrow views are often the most pronounced, and if they become dominant are liable to bring down the standard of an amalgamated society instead of enlarging its sphere of usefulness; besides, this amalgamation necessarily entails a certain loss of income by the loss of double subscriptions.

If my experience as a member of the council of most of the societies of which I speak does not deceive me, it should be the object of those who have the progress of anthropological studies at heart to induce the metropolitan societies to specialize their functions. The following might then become the titles of the various societies included under the term anthropology; and they would represent not only the natural divisions of the science, but practically the divisions which are most consonant with the organization of the existing societies. Setting history and historic archæology aside as beyond our province, we should have:—(1) Proto-historic archæology; I adopt the term proposed by Mr. Hyde Clarke for this branch, which practically includes all that comes under the head of Biblical Archæology at present; (2) Prehistoric Archæology; (3) Philology; (4) Biology, including Psychology and Comparative Anatomy, in so far as it relates to Man; (5) Descriptive Ethnology, viz. original reports of travellers on the races of man, conducted in association with geographical exploration. Under these heads we should, I believe, include all the various classes of special workers. These should constitute independent, but associated societies—that is to say, the members of one should be privileged to attend the meetings and take part in the discussions of the others, but not to receive the publications of any but their own society. By this means each would profit by the experience of the other societies, but the funds necessary for the maintenance of each would be secured. As branch sections of anthropology they would be under the control of a general

elected council only in so far as would be necessary to prevent their clashing with each other, and for the control of any measures which it might be necessary for the several sections to undertake in concert; under the auspices of the general council might also be held the anthropological meetings devoted to such general subjects as either embraced the whole or were not included in the sections. By this means the standard of anthropological science as a comprehensive study of the science of man in all its branches would be secured, and the possibility of its becoming narrowed under the influence of any dominant party would be obviated. It is hardly necessary to say that the chief advantage of such an arrangement as I suggest would consist in the employment of a single theatre and library for these cognate societies; they would employ a single printer, and the arrangements might include one or more artists, lithographers, and map-drawers, by which a great increase, and at the same time economy, would be effected in the illustrations. The saving effected by the union of these societies in a single establishment might be applied to conducting explorations, either at home or abroad, in connexion with the Geographical Society. The question of the utilization of apartments is one which commends itself especially to the notice of Government in regard to those societies for which apartments are provided at the public cost. It should be made a *sine quâ non* that the societies so favoured should fairly represent all the branches of their subject.

As regards the local societies, it has been proposed to republish a selection of their papers under the auspices of this Association. It is to be hoped that some arrangement, such as that proposed by the committee of which Sir Walter Elliot is secretary, may be carried out. I have only one suggestion to make on this point: republication is simply a repetition of cost and labour, if the desired object of bringing the papers together can be accomplished by other means. As to selection, I have no faith in it. If local and metropolitan societies could be induced to adopt a uniform size for their publications, not necessarily a uniform type, the papers relating to the same subjects might be brought together without the cost of reprinting. It would only be necessary to establish a classification of papers under various headings, such as, for example, those which constitute the sections of this Association. The societies might then print additional copies of their papers under each heading, in the same manner that additional copies are now struck off for the use of authors. A single metropolitan society might be recognized as the representative of each branch, and under its auspices the whole of the papers of the local and metropolitan societies relating to its branch might be brought together and printed in a single volume. Time does not allow me to enter into the details of the arrangements which would be necessary to carry out such a measure. I believe the difficulties would not be so great as might at first sight appear, especially as the evils of the existing arrangements are much complained of; but it should be a primary object of any arrangement that may hereafter be made that the independence of the several branches should not be sacrificed unnecessarily; it should be endeavoured to stimulate them and train them into useful channels rather than to bring them too much under central control.

My object in making these remarks has been not so much to bring forward any special recommendation of my own as to ventilate the matter amongst those of the public who take an interest in these studies, but who are not so intimately connected with the present working of the societies as to have any personal interest in them; and I trust that the importance of the subject will be thought to justify me in having brought it to the notice of the meeting.

It is to be hoped that whenever, as anthropologists, we parade for Dr. Livingstone's inspection (without, I trust, adhering too closely to the costume which he has suggested for that occasion), it may be found that if we cannot compete with his friends the anthropophagi in point of bone and muscle, in all that relates to organized division of labour and mutual cooperation we may not be found wanting in that superiority to our *betters* which might naturally be expected from the advanced civilization which we enjoy.

On the Predominating Danish Aspect of the Local Nomenclature of Cleveland, Yorkshire. By the Rev. J. C. Atkinson.

A careful study of the place-names in Cleveland has led the author to the general conclusion that upwards of 80 per cent. of the genuine old forms in this district are certainly of Danish origin. It appears that only a few of the ancient local names can be referred to Anglian sources; in fact the Anglian element in Cleveland history may have been altogether subsidiary.

From an analysis of the names of places, as preserved in the Domesday Book and in writings of more mediæval date, the author finds 50 names ending in *-bi*, 13 in *-thorp*, 12 in *-thwaite*, 31 in *-dale*, 14 in *-um*, 7 in *-grif*, 8 in *-cliff* or *-clive*, 3 in *-borg* or *-burg*, besides about 55 not specially classed; and from the early date of the occurrence of these names hardly 1 in 50 admits of any doubt as to its essentially northern origin. In addition to these, there is a very large number of names, belonging to the classes in *-dale* and *-clif* and to the groups in *-rigg*, *-sike*, *-holm*, *-keld*, *-sty*, *-wyke*, *-wath*, &c., which are not included in the author's lists because there is no documentary proof of their imposition previously to mediæval times. It is almost certain, too, that not a few of the names in *-ton* &c. have a northern origin. On the whole, out of something under 250 Cleveland names, dating back to mediæval times and yet earlier, upwards of 210, or considerably more than 80 per cent., must unhesitatingly be ascribed to a Danish as contradistinguished from an English or Anglian source.

Exploration of some Tumuli on Dartmoor. By C. Spence Bate, *F.R.S.*

The tumuli on Dartmoor are generally cairns of stone. Three of these were explored on Penbeacon, and a very large one on Threebarrow Tor. The whole of these appeared to have been previously rummaged. In one of those on Penbeacon the remains of an urn of coarse pottery were found scattered about, and the kistvean had the capstone fallen in; amongst the soil within was found an implement of a long oval form, made out of white slate. The author believed this, from its worn appearance at the ends and sides, to have been made use of by the potter in forming the rudely shaped urn, such pieces of slate being still in use for that purpose in some parts of Ireland.

On Hamel Down are several tumuli that differ from those of Dartmoor generally. Among these were three built of earth only, margined round by small moorland stones. This neighbourhood being associated with such Scandinavian names as Grimm, Hamel, &c., the author thought that an exploration of these barrows might throw some light as to whether or not these old Vikinger visited Dartmoor for that tin which was essential for the manufacture of their bronze.

In the barrow, after removing a large quantity of earth, about halfway between the circumference and the centre, five large stones were found lying side by side on the surface of the ground; beneath one of these stones were found some burnt bones and a bronze dagger-blade chased with lines along the sides and with dots at the base: an oval ornament of amber inlaid with gold fits in lines corresponding with the longer and shorter axes.

This feature in the interment, together with the circumstance that the burnt bones were not enclosed within an urn, offer strong evidence, the author contends, of the intrusion of the old Norsemen into these regions in a very early stage of the Bronze period.

Note on a Visit to the Hypogeum. By J. F. Campbell, *of Islay.*

The author read extracts from his diary, descriptive of a visit to the hypogeum on October 4, 1871. His description was illustrated by several sketches, and agreed substantially with that of Mr. Carmichael. A box of bones was taken from the spot by the author and submitted to Professor Owen.

Notes on the Looshais. By ARCHIBALD CAMPBELL, *M.D.*

For a long time the Looshais were best known to us under the name of Kookies, and it is even now not quite clear how far the two terms are properly convertible, or should be used to designate separate tribes or the divisions of one tribe.

The Looshais inhabit the hill-tracts of Chittagong and those adjoining that British province, whence they extend north and north-east till they reach Cachar on the one hand and the frontiers of Burmah on the other. They form one of the numerous tribes generically known as the *Toungtha*, or Children of the Hills. Their complexion is fairer than that of the people of the plains; their features resemble those of the Malays more than the Tartar-faced people of Munipore; and their language is said to be remarkable for euphonic sweetness compared with the harsh and guttural dialects of the Tartar races to the north.

The Looshais dry and preserve their dead; they have no distinctions of caste; marriage is a civil contract dissoluble at the will of the parties concerned, and there is no prohibition against the marriage of widows. The men live by hunting and marauding, while cultivation and all household work is left to the women. They live in log-houses on the ridges of the hills, and know enough of iron-working to make spear-heads and fish-hooks.

Hitherto the Looshais have been known only as a savage and murderous race; but the author quoted from the recent official reports of Brigadier-General Brownlow, C.B., Brigadier-General Bourchier, C.B., and Mr. Burland, who accompanied the expedition against the Looshais, to prove the excellent character of their social organization, the mildness of their disposition, their general intelligence and industry, and their aptitude for trade. The author expressed a hope that the Looshais would, in the progress of tea-planting in Cachar, be induced to adopt its cultivation in their own hills, and would also join the coolie bands working in the British districts.

On a Hypogeum at Valaquie, North Uist. By A. A. CARMICHAEL.

In this paper the author described an underground dwelling at Druim-nah-Uamh, in Valaquie, on the north-west coast of North Uist, one of the Hebrides. Although the structure was discovered ten years ago, but little was done to ascertain its real nature until last year (1871), when the author caused the sand, which nearly filled the building, to be removed, and thus exposed the true form of the hypogeum. On the floor of native sand a large quantity of bones, teeth, and shells was found: the bones were chiefly those of the deer, ox, pig, and sheep; the shells were those of the limpet, mussel, cockle, and periwinkle, with a few broken scallop-shells. Mingled with these remains were charcoal ashes, broken pottery, the tine and antlers of the red deer, and the upper half of a small quern.

The ground-plan of the hypogeum is crescentic. The walls run parallel to each other, and two stone lintels cross the house from side to side. The west end is at right angles to the sides, while the east end is curved. A dome roof is raised by overlapping stones, terminating in a cap, and giving the roof the appearance of a flattish beehive. The entrance is near the middle of the inner wall. There are four recesses in the walls.

The form and position of the hypogeum are peculiar; but the author points out its general resemblance to a structure on Mr. James Macpherson's property, described by the late Sir David Brewster.

On Sussex River-Names. By Dr. CHARNOCK, *F.S.A.*

The paper gives the etymology of the principal Sussex river-names. After a dissertation on the rules relating to etymology, the author shows that most of the names coincide with other European river-names, that many are etymologically the same word, and that most of them have been named by the Kelts, either from a pure Keltic root or from a word corrupted by them from the Greek or Latin. Among other names traceable to the same root are Adur, Rother, Ouse, Asten, East[bourne], and Ritch.

On certain Geographical Names in the County of Sussex. *By* Dr. Charnock, *F.S.A.*

Among other names, the paper attempted the etymology of the following:—Fairlight may translate in Saxon beautiful meadow (*fæger-leag*), but is more probably the same as the English local names Farley, Farlie, Farleigh, from the Danish-Saxon *faar-leag*, sheep's meadow. The author discards the usual etymology of Hastings, and gives two suggestions, viz. from Danish *hest-eng*, horse meadow, and *Asten-enge*, meadow of the Asten, a stream which runs through the battle-field. Framfield is for Frantville, etymologically the same as Frant, which gave the ancient appellation of Frant Wells to Tunbridge Wells; from Danish *vand*, water. The ancient name Senlac is from *seen-leag*, beautiful meadow. The author compares Aderida with Anderitium in Senonia Lugdunensis, Andetrium in Illyria (the Andretium of the Peutinger Table), and also with the Anderitum of Ravennas, a town of Aquitanian Gaul (now Javols in the Gevaudun), which the author derives from Keltic *annedd-ar-rid*, a dwelling near a passage or ford. Mutuantonis may be from *mant-an-ton*, mouth of the water, or *mwth-ant*, rapid river.

Roumanian Gipsies. *By* Dr. Charnock, *F.S.A.*

By the census of 1860 the Roumanian gipsies are put down at 300,000. They are well-formed and long-lived. There are, however, many cripples from artificial causes. They are adroit in work, but work very little, and pass whole days in sleep. They are fond of carrion, and are great cowards. Chastity is scarcely known. Their ordinary diet is a polenta of maize called *mâmăliga*. Men, women, and children smoke from the age of five. The native dance is the *tânană*. Most of them have fixed residences. The Vâtrassi class are all well built, have beautiful black eyes and long black hair. On becoming mothers the women are very ugly. The people have entirely forgotten their native language, and have lost the manners and usages of gipsies. The best musicians are found amongst them. Some are engaged in agriculture, and they are more civilized than the Roumanian peasants.

The paper concluded with full remarks on the grammar, and a comparative vocabulary of the dialect with other gipsy dialects and also with the Indian languages.

On the Gipsy Dialect called "Sîm." *By* Dr. Charnock, *F.S.A.*

The dialect in question is spoken by Egyptian gipsies in the presence of strangers and for secrecy. The author traces most of the words to the Arabic, concealed by prefixes or suffixes and sometimes by both. The Egyptian suffix *ish* (under various forms) is found in a great many words. Other suffixes are *mi*, *ma*; and *āh*, *eh* are used as prefixes. The paper contained many examples, including numerals. The word Sim is probably from *el-sīmiyā*, for *el kimiyā*, secrecy.

On the Ethnological and Philological Relations of the Caucasus. *By* Hyde Clarke.

This paper communicates the further researches of Mr. Hyde Clarke on the classification of the languages of the Caucasus. It identifies:—(1) the Ude with the ancient Egyptian and Coptic; (2) the Abkhass with the Agaw, Falasha, &c. of the Upper Nile; (3) the Circassian with the Dravidian; (4) the Georgian, Lazian, and Suan with the Caucaso-Tibetan. The Ude and Abkhass are connected with the statements of Herodotus (Book II.) as to the Egyptian colony established in Colchis by Sesostris. Mr. Hyde Clarke observed that the Caucasus was not a centre of population for the world, but a place of passage, and showed the relations of the Abkhass (Agaw) and Circassians with their congeners in Europe, Africa, Asia, Australasia, and America (Omagua, Guarani), illustrating the common population of the new and old world, and the knowledge of America by ancient nations, dimly preserved though not understood by the Greek and Roman geographers.

On the Mangnema or Manyema of Dr. Livingstone. By Hyde Clarke.

The author identifies this population with the Niam-Niam or Nya-Nya of the White Nile, as cannibals, with saw-teeth and the same ethnological characteristics. He referred to the statements that some of the men have a deformity of the os coccygis.

On Tumuli at Ascheraden in Livonia. By Charles T. Cröger.

(Communicated by Baron N. C. Bogouschevsky.)

In 1837 a fearful inundation laid open, near Ascheraden,—so called, perhaps, because the Ask-men (navigators) used to put up their boats (Ask) in this place,—in Livonia, the contents of some tumuli.

In most of these the following objects were discovered:—Bodies lying with faces upwards, the arms placed crosswise on the breast and ornamented with spiral-shaped bracelets; some of these were dressed in a linen shirt made out of very delicate strings fastened together; over the shirt a woollen overcoat of a greenish-brown colour, with metallic wire interwoven with the cloth, the whole tied round the waist by a leather girdle fastened by means of a metallic brooch. Breeches (in some cases of cloth and in some of linen) fastened under the knees, and on the finger-bones brass rings. The head ornamented with a bandage (sometimes perfectly smooth, sometimes pressed into the shape of a zigzag); also a kind of cap made of spiral rings, which, being fixed on woollen bands, terminate in a point.

The ornaments on the neck consist chiefly of strings of glass and amber beads and gilded or silvered balls of clay. From the shoulders to the knees hang rows of chains (sometimes ninefold) covered with amulets in the form of birds, or with household implements, such as keys, knives, &c. Spears with points ornamented with silver, sheaths for arrows made of the bark of trees (such as birches) fastened together by bands of metal, &c. Very few iron swords were discovered, but a large quantity of coins, of various ages, were found with the bodies of *warriors* only. Among the coins were some Greek coins from Thasos, Roman coins from the third century B.C. down to Emperor Valentinian, Anglo-Saxon and Danish coins from the earliest times down to the twelfth century, German coins from the time of Otto I. to the eleventh century, coins of Wisby, and Arabic Dyrrhems from 757 to 1011 are very common.

Note by Baron N. C. Bogouschevsky.

To judge by the general appearance of these bodies, their dress, and the detestation which the inhabitants of the country entertain even at the present time for these sepulchres, calling them "the sepulchres of monsters," they do not belong to any of the Tchudic, Sclavonic, or Wend nations, but to the pilfering Northmen, who made continual invasions into Greece, Constantinople, &c., very often choosing (as can be seen from M. Karamzin's 'Hist. of the Russian Empire') this road, through the rivers Dwina and Dnieper into the Black Sea, and then following the west coast as far as Constantinople, but very often proceeding further, into the Mediterranean, &c. As they came back by the same road, they left numerous traces of their passages in the shape of tumuli, rows of which cover the whole length of country between Livonia in the north and the delta of the Dnieper in the south, and hidden deposits of Asiatic, Roman, and Greek coins, which in some cases of danger they were obliged to secrete, and afterwards were either prevented from returning to these deposits by various adversities, or perished on the way home, thus carrying their secrets with them to the grave.

Report on the Victoria Cave, explored by the Settle-Cave-Exploration Committee. By W. Boyd Dawkins, *M.A., F.R.S., and* R. H. Tiddeman, *M.A., F.G.S.*

Part I.—*The Archæological and Zoological Results.* By W. Boyd Dawkins.

Both geologically and historically, the results of the labours of the Settle-Cave-Exploration Committee in the Victoria Cave during the last three years are of

great importance. The cave is situated to the north of Ingleborough, and consists of several large chambers, often nearly filled up with earth and stones. The Committee began work by cutting a trench through a layer of stones broken from the cliff above; it proved to be resting on a dark layer composed of burnt stones and bones, fragments of pottery, and a few Roman coins. On following this layer right into the cave, several bronze-gilt ornaments, of Roman workmanship, were found, and others which certainly were not Roman, but which bore a strong resemblance, in design and execution, to Irish or Celtic works of art preserved in various museums. The Celtic short-horn, the goat, horse, and pig seem to have been the principal food of the dwellers in the cave, from the great quantity of their bones which were discovered.

The strange mixture of articles of luxury and ornament in so wild a place seems only accountable by the supposition that the cave was inhabited, as a place of refuge, by some well-to-do Romano-Celtic family, who carried off with them into their place of retreat many of their valuables, cattle, and other property. The date of this occupation seems to lie between the fifth century, as shown by the barbarous imitations of Roman coins, and the first quarter of the seventh century, when the kingdom of Strathclyde was conquered by the Northumbrians. But, besides this, evidence was found of a much older occupation. Underneath the Romano-Celtic layer, at the entrance, pieces of chipped flints, broken bones of ox and bear, and rude bone implements prove that man inhabited the cave at a lower level, and therefore before the accumulation of the talus on it.

The grey clay on which these more ancient traces of men rested offered a serious obstacle to further examination, since it was more than five and twenty feet in thickness within the cave, and contained no remains of men or of animals. The Committee did not stop here, however, in their work. They have lately sunk another shaft, and have been rewarded for the great labour of this last enterprise by the discovery of a still older occupation of the cave by hyænas; their broken bones, teeth, and coprolites show that they must have lived there in large numbers, and the gnawed bones of rhinoceros, cave-bear, mammoth, reindeer, &c. show on what animals they preyed. It is very probable that these remains belonged to animals that inhabited Yorkshire in the preglacial stage of the Pleistocene period, and that the stratum above the cave-earth is of glacial age. The fauna to which they belong invaded Europe before the refrigeration of climate that culminated in the ice-sheet of Northern Europe, and remained in the area north of the Alps and Pyrenees *after* the ice-sheet had disappeared from the lower ground.

Part II.—*The Physical History of the Deposits in the Victoria Cave.*
By R. H. Tiddeman, *M.A., F.G.S.**

The cave was described as consisting of three principal chambers—a central one running N.N.E., about 40 yards long, and two others branching off from it to the right and left. It is probable that these chambers are really but one cavity filled with material up to inequalities in the roof which now separate the chambers, for the floor has never yet been reached.

The deposits were described in order of succession, beginning at the surface.

No. i. The *débris* at the entrance is still forming and is undoubtedly derived from the cliffs above by the frosts of successive winters. The author was of opinion that no trustworthy calculations of absolute or relative time could be based upon the thickness of this deposit, the rate of its formation being evidently far from regular.

Several floors of occupation are interbedded with this outside the cave, and inside they lie unconformably on the surface of the lower beds next to be described. They have been treated of fully by Mr. Dawkins.

No. ii. The entrance *débris* graduates below almost imperceptibly into a yellowish-brown clay full of angular fragments of limestone, with occasional beds of stalagmite. It is thinner at the entrance, but inside attains a thickness of 10 or 12 feet. Large masses of limestone lie on its surface, which have evidently fallen

* For fuller details and later discoveries, see an article by the author in the 'Geological Magazine,' vol. x. p. 11 (1873).

from the roof. The fragments are angular, and show no signs of rolling or glacial scratches.

No. iii. Below this Upper Clay-with-stones, wherever penetrated, we find a thick bed of fine dark-brown laminated clay. The laminations are very distinct and tolerably regular; the clay flakes off along the planes of bedding, the alternations consisting of excessively fine sand and tenacious clay.

It dips steadily towards the inner part of the cave, having an inclination of about 1 in 9, rather more than 6°. It shows a thickness of 12 feet in a shaft sunk in the left-hand chamber. With acid it effervesces freely, losing about 8 per cent. of its weight. Though very well adapted for preserving organic structures, it has not yielded a trace of any organism even to the microscope.

No. iv. The lowest set of beds yet attained comes next in order of descent. They are in all respects similar to No. ii., the Upper Clay-with-stones, save that in them, near the entrance, at a depth of about 16 feet from the base of the laminated clay, the group of older mammals, as mentioned by Mr. Dawkins, was discovered.

The origin of the *débris* at the entrance is clearly subaërial, and it must all of it be postglacial, for any glacier passing down the valley would infallibly remove it.

The similarity of the deposits ii. and iv. is so great that there can be little doubt that they were made under similar conditions and are due to similar causes. The angularity of the fragments and the absence of distinct bedding, save where stalagmite occurs, forbid us referring them to the sea; nor can they be referred to a river, for any stream of sufficient strength to bring the blocks would certainly have sorted the materials. It is not likely that they are glacial, and have been pushed into the cave from the side of an advancing glacier; for then they would have exhibited some scratches, which is not the case. It seems more probable that the stones have fallen from the roof, and the clay has been introduced by water in small volume coming down through crevices in the limestone and forming, where conditions were favourable, beds of stalagmite.

In direct contrast to the beds above and below, the laminated clay shows the greatest regularity of structure.

If it were marine, it seems unlikely that in so good a preservative medium no fragments or fibres of organisms should be found; nor against a rocky beach would it consist of such fine material; also, we should not expect to find it dipping away from the sea, but towards it or lying horizontal: neither have we anywhere in the district, for miles around, any indisputable evidence of the sea having been at so great a height (1450 feet) during or since the glacial period; any brook flowing through the cave at so high an angle would not deposit fine mud but remove it.

The author suggested that the moraine rubbish of a glacier or ice-sheet at some time blocked the entrance*, that water charged with mud by the constant grinding of the glacier trickled through into the cave, and that the frequent change from daily flow to nightly inaction gave rise to that close lamination in the deposit which is its characteristic feature.

This explanation of the glacial origin of the laminated clay was suggested to the Settle-Cave Committee, in a report in the spring of 1871, by the author.

Since then he has found in a shaft sunk at Ingleton, a few miles to the N.W., under 39 feet of till, laminated clay undistinguishable from that in the Victoria Cave, save in the presence of a few well-scratched small boulders and the crumpling of the beds. He considers it probable that this laminated clay was a deposit from glacier-water in some quiet hollow beneath the edge of the ice-sheet or its waning representative.

On the Primitive Weapons of Ancient India.
By Sir WALTER ELLIOT, *K.C.S.I., F.L.S.*

The earliest known inhabitants of India are now only found in their original unmixed state on the mountainous plateaux of Central India, on the Rajmahal Hills in the north, and in some other secluded situations; but their descendants

* This suggestion has since been confirmed (Geological Magazine, vol. x. p. 15, 1873).

are largely intermixed with the people of the plains, especially among the lower castes.

Most of these speak dialects of the Dravidian tongue, and in their hunting-excursions make use of a curved stick, which they throw with great dexterity, the concave edge being directed to the object. Hares, birds, and even deer are killed with them.

From this primitive form many of the modern metallic weapons appear to have been derived, such as the *coorg* knife or axe, in general use on the Malabar coast, the *kukri* of the Gurkhas, in Nepal, and the common woodman's knife throughout India—all of which are curved and have the cutting-edge on the concave side. These knives, or choppers, are also used as instruments of sacrifice, with which the heads of the victims, even of the buffalo, are often severed by a single blow.

Prof. Huxley, in his fourfold classification of the varieties of the human race, has found what he terms the Australoid division to be represented by the Australians proper, the Hill tribes of Central India, and the Ancient Egyptians. Now it is remarkable that among all these the throwing-stick is or has been in use. The boomerang of the Australians is well known; a similar weapon is depicted in the hunting-scenes on the walls of the tombs of the kings at Thebes, and in India it is found to be still in use by the inhabitants of the wilder districts, the descendants of aboriginal races.

Such coincidences can hardly be accidental, and they afford a remarkable support to a deduction drawn from totally different premises.

The Egyptian "throw-stick," according to Sir Gardener Wilkinson, which he found represented on the sculptured walls of temples, is still in use among the Desert Arabs, and is a formidable weapon in their hands. The Kaffir club made out of the long horn of the *Rhinoceros simus* may be of similar origin.

On the Alphabet and its Origin. *By* John Evans, *Esq., F.R.S., F.S.A., &c.*

After mentioning the labours of Gesenius, De Rougé, and Lenormant on the Continent, Professor Hewitt Key, Professor Rawlinson, and Mr. E. B. Tylor in England, who had, as well as others, done much to throw light on this field of research, the author treated the subject under three heads:—

1. As to the origin of writing and the method of its development in different parts of the globe;
2. As to the original Alphabet from which that in common use amongst us was derived; and
3. As to the history and development of that original Alphabet.

So mysterious does the power of conveying information to others by writing appear to savages, that they regard written documents as no less than magical, and have been known to hide them at the time of committing a misdeed which they feared might be discovered by their means. Yet many of those in the lower stages of civilization have some ideas as to pictorial records.

The cave-dwellers of the south of France at a time when the use of metals was unknown, and when reindeer formed one of the principal articles of food in that part of the world, possessed considerable powers of drawing and of sculpture. On some of their bone instruments figures of animals are engraved, which possibly may to the original owners have conveyed some reminiscences of scenes they had witnessed when hunting. Among the Esquimaux such records are frequently carved on their weapons, and the taking of seals and the harpooning of whales are often depicted. Capt. Beechey says that he could gather from these representations a better insight into the habits of the people than could be obtained from any signs or other intimations.

Among the North-American Indians the system of picture-writing has been more fully developed, and numerous instances are recorded in Schoolcraft's 'Indian Tribes.'

In Mexico the art of pictorial representation had at the time of the Conquest been carried to great perfection. The bulk of the pictures, however, merely re-

present wars, migrations, famines, and scenes of domestic life. They were, moreover, able to record dates by means of an ingeniously devised cycle, and had some idea of attaching a phonetic value to their symbols.

In Peru, though some sort of hieroglyphic writing appears to have been known, the chief substitute for writing was the Quipu or knotted cord. This consisted of a main cord with strings of different colours and lengths attached. The colour, the mode of making the loops, knots, or tufts, their distance from the main cord or from each other, had all of them their meaning. Each Quipu had its own keeper or interpreter, and by their means all public accounts were kept. The Wampum in North America was of somewhat similar character, and in Polynesia also the same sort of Quipu is in use.

There is a tradition among the Chinese of a similar system of recording events by means of a knotted cord having been in use among them previous to the invention of writing. The Chinese system of writing, though far superior to that of the Mexicans, is still not alphabetical, but syllabic. At the outset the characters seem to have been pictorial; but the representations of the objects have now become so much conventionalized and changed, partly in consequence of the method of writing by means of a brush, that there is much difficulty in recognizing them.

With a monosyllabic language, the words of which are of necessity limited in number, one sound has often to represent more than one sense, and the Chinese characters have therefore been divided into phonetics or radicals—those which give the sound, and the classificatory or determinatives, or those which give the sense.

The Egyptian hieroglyphics present much analogy in character with the Chinese method of writing. In their earliest form they seem to have been principally pictorial, though also at the same time symbolic. The next stage would appear to have been syllabic, when a certain sign represented a syllable, though often with a second more truly literal sign affixed, denoting the final consonant of the syllable. To prevent mistakes, the signs representing words were often accompanied by other signs, which were merely determinative of the meaning. Thus three horizontal zigzag lines representing water, showed that the previous symbol designated something connected with liquids—or two legs walking, that the word bore reference to locomotion. Many hieroglyphics, however, appear to be purely literal, though, in the case of consonants, often having some vowel sound implied. These literal hieroglyphics stand for the initial letters of the objects or ideas they represent: for instance, a goose flying is the equivalent of P, the initial of *Pai*, to fly; an owl stands for M, the first letter of *Mulag*, the Egyptian name of the bird.

The more careful pictorial representations of the objects such as are to be seen in sculptured hieroglyphics and in formal inscriptions required, however, too much time for their execution to be adopted as an ordinary means of writing. In consequence the signs became conventionalized, and the salient characteristics of the object were seized on for the more cursive form of writing known as the hieratic. From this, again, was derived the writing known as demotic, in which many of the symbols have become so much changed and simplified that it is with difficulty that they can be identified as descendants of originally pictorial forms.

A modified form of hieroglyphic writing is still in use among us, more especially in connexion with the science of astronomy; and the conventional forms which now represent the signs of the Zodiac are very instructive as to the amount of modification such symbols are liable to undergo.

In Aries (♈) and Taurus (♉) the heads of the ram and the bull may still be recognized. Gemini is represented by the twin straight lines, ♊; Cancer by its claws, ♋; and Leo by its head and tail, ♌. In the symbol for Virgo there appears to have been some confusion between Astræa and the Virgin Mary, the sign being symbolized by the letters 𝔪𝔳, ♍. The scales of Libra, the sting of Scorpio, and the arrow of Sagittarius can still be traced in the symbols, ♎, ♏, ♐. The twisted tail of Capricornus survives in ♑, and Aquarius is represented by two wavy lines of water, ♒. The remaining sign of Pisces has been much metamorphosed; but the two fishes, back to back, with head and tail alternating, can readily be reconstructed from the symbol ♓.

The gradual simplification of form exhibited in these signs, and in the Chinese

and hieratic systems of writing, must be borne in mind when studying the development of other systems.

With regard to the origin of the alphabet in common use in Europe there can be no doubt, the testimony of classical historians, as well as that of the letters themselves, being conclusive as to its Phœnician source. But at what date letters were first in use in Greece is by no means certain; Grote thought that they were absolutely unknown in the days of Homer and Hesiod (B.C. 850–776). It seems, however, probable that they were introduced at a somewhat earlier date. If the date which has been assigned to the famous "Moabite stone," of about 900 B.C., be correct, the correspondence in form between the archaic Greek letters and those on the stone raises a strong presumption in favour of letters having been imported into Greece at the time when the Phœnician alphabet was in that stage of development in which it occurs on the stone.

Even the name of the alphabet preserves the memory of its Phœnician origin, for Alpha and Beta, the names of the two letters from which the word is derived, are not really Greek, but merely the Hellenized forms of the Phœnician Aleph and Beth. The same is the case with the names of all the other Greek letters down to Tau, the last five letters, Υ, Φ, Χ, Ψ, Ω, being of later introduction.

The correspondence in form between the Roman, the Greek, and the early Phœnician alphabet, as given on the Moabite stone, can readily be traced. It must, however, be remembered that the letters of the latter are written from right to left, or in the same manner as Hebrew, and not, as is the case with us, from left to right. In the early Greek inscriptions it appears to have been a matter of indifference in which direction the letters were placed. In some the lines are alternately in either direction; and this form of writing was known as Boustrophedon, or that which turned backwards and forwards like an ox in ploughing.

As to the original identity of these three alphabets there can be no doubt; neither can any exist as to the order in which the letters were originally arranged; for in the Hebrew Scriptures, the language of which may practically be regarded as the same as the Phœnician, there are several instances in which a succession of passages, each commencing with a different letter of the alphabet, present them in this order. A well-known example is afforded by the 119th Psalm, each of the twenty-two sections of which commences with a different letter, the name of which forms the heading to each in the English version of the Bible.

When, however, we come to consider the history and development of the Phœnician alphabet, we are no longer upon so sure a footing. The manner in which some other forms of writing such as the Chinese and the Egyptian hieratic, were developed will have prepared us for the probability of the Phœnician alphabet having also been evolved from a pictorial source.

It is a by no means unimportant fact, in reference to this view, that the names of the Phœnician or Hebrew letters are not arbitrary, but each significant of some object, though the meaning of the names cannot in all cases be recognized with absolute certainty. For instance, Aleph, Beth, Gimel, and Daleth mean Ox, House, Camel, Door; and if we find that these and the succeeding letters, when in their most primitive forms (so far as known), present similarities with the whole or a portion of the objects by the names of which they are distinguished, there is a strong probability of a pictorial origin for the letters.

Taking the forms of the letters, as given on the Moabite stone, in conjunction with the meaning of their names, such a similarity can in all cases be traced, though more certainly intentional in some letters than in others. This will be best shown in a tabular form* (p. 184).

This correspondence in form can hardly be appreciated without diagrams, but in many instances is striking, and in none absolutely forced. There have, however, been numerous objections raised to such a view of the derivation of the forms of the Phœnician letters.

Lenormant and De Rougé would rather trace them to Egyptian hieratic characters; but the resemblances they point out between them are but slight, and in no instance does the Phœnician name of the letter agree with that of the object repre-

* The letters are here given in the ordinary Hebrew character instead of the older form.

sented by the Egyptian hieratic. Moreover the resemblances, when traced, are rather with later forms of Phœnician letters than with those on the Moabite stone.

א Aleph	An ox..........	*The head of an ox.*—That this letter was known to embody this symbol is recorded by Hesychius about A.D. 380. The correspondence of a small a or *a* with the sign for Taurus when placed horizontally (α) is worth notice.
ב Beth......	A house or, possibly, a tent.	*A house, showing one wall and the ridged roof.*
ג Gimel	A camel........	*The head and neck of a camel.*
ד Daleth	A door	*The triangular door of a tent.*
ה He........	A lattice or window.	*A lattice* (?).—The meaning of the name of this letter is somewhat doubtful.
ו Vau	A peg or nail ..	*A peg.*
ז Zain	A weapon	*An arm holding a spear* (?).
ח Cheth	An enclosure, or field.	*An enclosure.*—Much like the Chinese figure for the same meaning.
ט Teth	A serpent	*A coiled snake.*—This letter does not occur on the Moabite stone.
י Jod	The hand	*The hand and wrist in profile*, similar to what may be seen on some early Hindu coins.
כ Caph......	The palm of the hand.	*An open hand*, as in some drawings of the North-American Indians.
ל Lamed	An ox-goad	*An ox-goad* (?).—The meaning of the name somewhat doubtful.
מ Mem......	Water	*A wavy line.*—Like the representation of water on early coins and sculpture, and as in the sign of Aquarius, ♒.
נ Nun	A fish..........	*The head, gill, and back of a fish.*
ס Samech....	A support	*A kind of prop supporting a trellis for vines.*—Mr. Hensleigh Wedgwood has pointed out the similarity of this letter to the figure of a sculptor's bench or easel in Egyptian pictures.
ע Ain	The eye	*The pupil of the eye*, as in Egyptian hieratics.
פ Pe........	The mouth	*The two lips open at an angle*, much like the mouth as represented on some ancient British coins.
צ Tsade	A reaping-hook..	*A reaping-hook or scythe attached to its handle.*
ק Koph......	The back of the head (?).	*The head and neck* (?).
ר Resh......	The head	*The head in profile.*
ש Shin	A tooth	*A tricuspid tooth.*
ת Tau	A mark	*A cross*, like the mark still made by those who cannot write.

Mr. E. B. Tylor also considers that the theory maintained by Gesenius of the Phœnician letters being pictorial can be shown to be unsafe. He thinks the resemblances between the letters and the objects to be but small, and the bond which attaches the name to the letter to be but slight; that the coincidences are not primary and essential, but secondary and superficial. He suggests that Hebrew words may have been chosen as names for letters derived from some extraneous

source, such names having the proper initial letter and also some suitability to describe its shape; the same as if in English we called

A—Arch or Arrowhead. B—Bow or Butterfly. C—Curve or Crescent.

This, however, is contrary to all analogy among methods of writing of which we know the development; and moreover, several of the names of the Hebrew letters are not actual words in common use in the Hebrew writings, but words which have become obsolete, and of which, in one or two cases, it is hard to recover the meaning. The letters, moreover, cannot originally have been mere arbitrary signs, or there would have been greater distinctions between some of them, such as it was subsequently found desirable to introduce.

If, too, the Phœnician letters came from an extraneous source, we may well ask where it was, and how it happens that no traces of the original names of the letters have been preserved.

It seems far more probable that the Phœnicians, possibly in the first instance borrowing the idea from the Egyptians, struck out for themselves a more purely literal and therefore a more simple and useful alphabet. A classification of sounds once established, and a system of syllabic symbols once invented, the transition to a pure literal alphabet is comparatively easy, especially when once the syllabic symbols have, from the introduction of foreign words or from other causes, been employed for the initial sound only of the syllables they represent.

Such a change, involving a departure from old practice, might perhaps more readily take place in an adjacent country to that in which the syllabic system prevailed than in the country itself; and we may readily conceive a practical people like the Phœnicians importing from Egypt a system of pictorial writing thus modified.

Certainly their alphabet, unlike the letters of the later class of Egyptian hieroglyphics, does not appear to consist of merely a few survivors from a whole army of symbols. On the contrary, it seems to present some traces of arrangement; for the objects representing the letters appear to be grouped in pairs, each comprising two objects in some manner associated with each other; and between each pair is inserted a third letter, represented by an object not so immediately connected with those preceding it, but still not absolutely alien from them.

Thus the ox and the house are followed by the camel—an animal, by the way, not represented in Egyptian hieroglyphics. The door and the window are followed by the peg; the weapon and enclosure by the serpent; the hand and the palm by the ox-goad; the water and the fish by the support; the eye and the mouth by the reaping-hook; the head and the back of the head by the tooth; and the alphabet concludes with the final mark, ×.

It would be superfluous to attempt to point out the bearings of this question of the origin and development of the Phœnician alphabet on the history of civilization in Europe and Western Asia.

Future discoveries may possibly bring us nearer the cradle of this alphabet; but it seems probable that on the Moabite stone we find the letters still retaining enough of their original pictorial character to justify a belief that they there occur in a comparatively early stage, and not removed by many centuries from the time when they were merely delineations of the objects the names of which they have preserved. Assuming this to have been the case, what is the stage of culture to which the inventors of this alphabet appear to have attained?

They were not mere nomads or hunters, but a people with fixed dwellings for themselves and enclosures for their cattle; they were acquainted with agriculture, and had domesticated animals, and employed the ox as a beast of draught to cultivate fields, the produce of which they reaped with metallic sickles. In fact their civilization would seem to have been at least equal to that of the bronze-using people of the Swiss lake-dwellings.

A Pata-patoo from New Zealand. *By* Sir Duncan Gibb, *Bart.*

The author was presented with a stone weapon called pata-patoo by his friend the late Capt. Lowe, who had been an old traveller among the islands of the

Pacific. It was obtained in the Society Islands, but had come originally from New Zealand, and, although of recent manufacture, now extremely difficult to obtain. The present example was composed of dark-green basalt smoothly polished, 12 inches long, and weighed $1\frac{1}{2}$ lb., thus forming a powerful weapon for striking the top of the head. Indeed the alleged use to which it was put by the inhabitants was to dispatch old people when they became infirm (their parents for example), by a blow in the middle of the top of the skull inflicted from behind when it was least expected. This blow was sufficient to split the skull, and death was instantaneous. The hard and compact nature of the stone rendered it a safe weapon to accomplish its end. This terrible custom, which the author's friend learned had been at one time prevalent, has long ceased to be practised; no account of it appears in Capt. Cook's voyages, although he brought several of the weapons in stone and bone to England now preserved in the British Museum. In the Museum there were eleven pata-patoos (three of them bone), and in the Christie collection also eleven (two of them bone), the largest being 18 inches long and the heaviest 3 lbs. in weight.

Stone Implements and Fragments of Pottery from Canada. By Sir Duncan Gibb, *Bart.*

The author referred to the discovery of stone implements and pottery throughout Canada, of various degrees of antiquity, the most recent being stone gouges, chisels, hammers, and domestic utensils. Arrow-heads and spears were more ancient, as they were not met with in recent sepultures, but generally were found on the surface of ploughed land. The implements which he had collected himself in Canada consisted of sixteen arrow-heads, two flat spears, and two axes. The spears were composed of chert, and were from the Saguenaye district, the largest being $4\frac{1}{4}$ inches long by 2 wide; they were well formed, flat, and thin. The axes were of polished green micaceous schist, wedge-shaped, from $3\frac{1}{2}$ to 4 inches long and $\frac{3}{4}$ of an inch thick; weight $7\frac{1}{4}$ and 4 ounces: found at Niagara. The arrows varied in their size, form, and composition, ranging in length from $\frac{7}{8}$ of an inch to $3\frac{3}{8}$ inches, being either long and narrow tapering to a point, or broad and rounded in shape; one resembled a small celt in form. They weighed from 16 to 340 grains, or close upon $\frac{3}{4}$ of an ounce, and ranged from $\frac{1}{8}$ to nearly $\frac{1}{2}$ an inch in thickness; the shaft varied in shape and length. The localities whence the sixteen arrows were obtained were Montreal, the Saguenaye, Pointe du Chênes on the Ottawa river, Chippewa, Niagara, William Henry, and Quebec; the greater number were composed of chert; one was of red slate, another of white quartz: on the whole they differed in form from the arrows found in the British Islands. As arrows were frequently found at Chippewa, it was evidently the site of some ancient battle-field, as no flakes nor chips were found associated with them. He also described three fragments of pottery, from the shores of Lake Erie and Montreal, all imperfectly baked. Looking upon the stone arrows and spears as the most ancient stone implements found in Canada, if not in America, the author was disposed to place the period of their use and manufacture at about 200 years before the Christian era, corresponding to the time that our forefathers in the British Isles might have used such things as weapons or objects of the chase. Nevertheless, if the time was considered at which the aboriginal inhabitants of America were traversing that continent and required some weapon as a means to kill game to subsist upon, 4000 years could not be looked upon as too remote; and as the arrow is the most primitive and the simplest implement we have any knowledge of, the author said it may be reasonably considered to have been employed by the inhabitants of Canada at that time, as well as probably over other parts of the North-American Continent.

On the Garo Hill Tribes of Bengal. By Major H. H. Godwin-Austen, *F.R.G.S., F.Z.S., &c., Deputy Superintendent to the Topographical Survey of India.*

The Garos occupy the extreme western end of the range of hills south of the Brahmaputra and Assam, and are allied to the Mech and Kachari. They do not erect

stone monuments, but we find a similar custom in the setting up of posts of wood with tables in front made of bamboo; and this has led the author to think that these very perishable constructions gave rise to the erection of the monolith and dolmen as seen in the Khasi Hills adjacent on the east, the object of both tribes in setting them up being as a propitiation of good fortune. Setting up curiously carved and peeled rods is another peculiar custom, particularly as it has been noticed by Mr. St. John in Arakan. The Atong clan is an interesting section of the Garo tribe, speaking a different dialect containing many words used on the Munipur side; this, with their better stature and appearance, points to a former emigration from that side. The use of the bow and arrow confined to the Khasi, the Garos carrying only spears and sharp swords, is an interesting fact in tribes living so close together.

Drawings of the graves and the carved posts &c. were given, and notice made of the dress and points of difference between the Langam and other Garos.

On the Barrows of the Yorkshire Wolds. *By the* Rev. W. Greenwell, *M.A., F.S.A.*

This paper was confined to a description of the *round* barrows and their contents. In general form these barrows are either conical or bowl-shaped. It is probable that many had originally an encircling mound or a ditch, or both, at the base; but if such were the case, all traces of these enclosures have been destroyed. The barrows were constructed of the materials nearest at hand, more commonly of earth than of chalk. They are usually associated in groups, but a single barrow is not uncommon. As a rule, they have been erected on high ground. Holes are often found under the mounds, sunk below the natural surface of the soil; the author suggests that these may probably have been the receptacles of food or other perishable material. Animal bones are usually scattered through the mounds, and appear to be the remains of feasts; flints and potsherds also occur among the materials of the barrows. The bodies buried under the mounds occur at various levels, the central burial being usually in a grave excavated in the chalk. Generally there is nothing to protect the body from the pressure of the overlying soil, interments in cists being almost entirely unknown in the Wolds. Rarely the body has been protected by a coffin formed of a hollow tree-trunk. The remains of the body, when burnt, are sometimes enclosed in a urn. Secondary interments are common, and the bodies previously buried have been thereby disturbed and the bones scattered. Some cases of apparent disturbance suggest the idea that the flesh may have been removed from the bones before burial, and the naked bones deposited in the barrow. In some instances the burials were by inhumation, in others after cremation, the former practice being by far the more common in the Wolds. The one process does not appear to have been older than the other; nor has the difference in question been one of social rank or of sex. In cases of burial by inhumation, the unburnt body is always found lying on the side in a contracted position, with the knees drawn up towards the head. This was evidently not due to the requirements of space, but must have originated in some settled principle, the meaning of which is not understood, but which appears to have been common to all mankind at a certain stage of development. Perhaps it was in imitation of the natural posture assumed in sleep when the individual sought warmth. The direction of the body seems to follow no rule. Some barrows are found empty—the so-called cenotaphs; but the author believes that in most cases such barrows have not been exhaustively searched; if really empty, he believes this due to decay of the skeleton, and not to the mound having been originally unoccupied. Charcoal is generally found associated with unburnt bodies; and the author suggests that this may be the remains of the fire through which the corpse was passed, when actually burning the dead had become to some extent a merely representative custom. If this be so, cremation must have been universal, even with those bodies which are apparently unburnt. It is likely that the unburnt bodies were laid in the grave clothed. The barrows contain numerous weapons and implements of stone (including flint), of bronze, and rarely of bone or horn. The catalogue of stone implements

includes almost all those which occur elsewhere, but the bronze articles are very limited; indeed, from the paucity of bronze implements and weapons, it is concluded that the barrows belong to a period before that alloy came into general use. It is notable that the articles in flint found in immediate contact with the bodies appear in most cases to be perfectly new, and as if made expressly for the burial; while those which are not found in association with an interment generally show signs of having been in use. In 248 burials by inhumation and after cremation, 39 had articles of flints or other stone, 10 of bronze, and 3 of horn. Ornaments and objects of personal decoration are occasionally found with the burials in the barrows, but are apparently confined to women. Out of the 248 burials only 5 possessed such objects; no gold, glass, or amber has been found; and, indeed, the whole of the evidence afforded by the barrows tends to show that they were the burial-place of a people in an humble condition, possessing but little wealth, and having but limited intercourse with other parts of the country. Vessels of earthenware frequently accompany the bodies buried in the barrows. Out of 248 burials, 69 were associated with pottery; and 7 of these vessels were cinerary urns holding the ashes of the dead. The vessels vary greatly in size, shape, quality of paste, and style of ornamentation. All the pottery is hand-made, unglazed, imperfectly baked at an open fire and not in a kiln. Broken stone is usually mingled with the clay. The ornamentation is confined to lines, generally straight lines. The author maintains that these vessels were not pieces of domestic pottery used in daily life, but were manufactured solely for sepulchral purposes. On the other hand, many of the potsherds scattered among the materials of the mound appear to be fragments of domestic pottery. Some idea of the diet of the early Wold-dwellers is derived from a study of the bones scattered through the barrows. These bones are referable to *Bos longifrons*, to an ox which was probably a cross between this species and the *Urus*, to the pig, the goat or sheep, the horse and the dog. Domesticated animals thus formed the main support of these people. Bones of the red deer are also, but very rarely, found. From the evidence afforded by the barrows it appears that the early inhabitants of the Yorkshire Wolds must have lived in an organized state of society, that they possessed domesticated animals and cultivated grain, that they manufactured woollen and perhaps linen fabrics, and that they had attained considerable skill in metallurgy and were acquainted with the manufacture of pottery, though ignorant of the potter's wheel. It is believed that it was their custom to bury with the dead the wives and children of the deceased, and perhaps their slaves. The round barrows yield both dolichocephalic and brachycephalic skulls. The short-headed race were taller, more strongly built, and harsher in features than were the long-headed people. With regard to the age of the round barrows, the author feels safe in not attributing to them too high an antiquity by referring them to a period which centres more or less in B.C. 1000.

Theories regarding Intellect and Instinct, with an attempt to deduce a satisfactory conclusion therefrom. By George Harris, *F.S.A., Vice-President of the Anthropological Institute.*

The author gave a concise summary of the opinions of Aristotle, Virgil, Origen, St. Augustine, De la Chambre, Des Cartes, Hobbes, Willis, Sir Matthew Hale, Dr. Henry More, Cudworth, Locke, Sir Isaac Newton, Priestley, Buffon, Dean, Dugald Stewart, Smellie, Sir W. Lawrence, Mr. A. Smee, Mr. Isaac Taylor, Mr. Herbert Spencer, Prof. de Quatrefages, and some other authorities; and observed that widely as these great authorities appear to differ one from another in their opinions, their several tenets are by no means irreconcilable, and the theories propounded by each are calculated to aid in arriving at a satisfactory conclusion as to the entire subject. Intellect and instinct, he thought, were like two countries, in many of their main features and productions nearly resembling each other, while in other respects they are strikingly and totally dissimilar. They differ essentially as regards the topics they embrace and their mode of dealing with these topics. Instinct only applies itself to matter so far as sensation proceeding from it conduces to this end; while Intellect not only takes

cognizance of it in this manner, but proceeds to various operations quite beyond these, of a far higher nature, and embracing the consideration of moral and abstract topics. In many cases animals are directly and uniformly impelled to do certain actions, in which they are guided mainly by sensation, and to their excellence in which they owe the perfect manner in which these operations are carried on. But in addition to this blind impulse, they exhibit a capacity of remembering, and deliberating, and reasoning to a certain extent and on certain matters, although they are utterly incapable of acquiring any of the sciences of reading, writing, or even speaking. Instinct is perfect as regards the ends for which it is adapted, but it is limited to these ends. Intellect has a far more extensive sphere, in which, however, it is far less perfect and unerring. A power of deliberating, as evinced by certain animals, seems almost necessarily to imply their endowment with some sort of immaterial being, analogous, although very inferior, to the soul in man—an opinion held by some of the distinguished philosophers whose opinions he cited.

Mr. T. McK. Hughes exhibited a series of fragments of chert which he had collected below a chert-bearing limestone on Ingleborough in Yorkshire. He explained how the chert got shivered as the limestone broke up along its outcrop, and the edges of fragments sticking out of the rainwash or drift clay got chipped by stones rolling down the slopes, by trampling, sheep, &c., while the frost finished the work. He pointed out that man seems generally to have dressed the edge of a flint by blows or pressure of somewhat equal intensity; whereas, except in rare instances, the chips taken off by nature varied according to the size of the falling stones, &c., and the position of the fragment being chipped.

He had made this collection since examining the flints in the museum at St. Germains, which are supposed by some to indicate the existence of man in the Miocene Period in France, but which he considered should be referred to some such agency as that he had just described.

On some Bone and other Implements from the Caves of Périgord, France, bearing marks indicative of Ownership, Tallying, or Gambling. By Prof. T. Rupert Jones, *F.R.S., F.G.S.*

A knife-like ivory plate, marked with regular pits, marginal notches, and groups of lateral scorings, from the Gorge d'Enfer, opposite Les Eyzies, on the Vezère, was the chief implement described and commented on. It is supposed by the author to have reference possibly to some gambling-transactions of the aborigines, as North-American Indians and others score their play on sticks and bones.

The shape, systematic pittings, crenulated edge, and scorings on this specimen were compared with known instances of such markings on ancient and modern implements of savage make. The author recognized simple and compound scorings and notches, similar to those made by Eskimo on their harpoons, as owner-marks on several weapons of bone from the French caves. Some which appear to be tally-marks, and several bearing either poison-grooves or capricious and aimless cutting and dotting, were also described and commented on.

Western Anthropologists and extra-Western Communities. *By* Joseph Kaines, *M.A.I. &c.*

The author commenced by asking, "What are the duties of Western Anthropologists to the less civilized communities of mankind?" In answering it, he said he should put out of sight altogether all considerations of a purely material sort, and look only at the normal aspects of the subject. He argued that the existence of the science of Anthropology depended on the preservation of the less civilized, since little or no knowledge of human evolution or development could be obtained but through them; and the past history of mankind, especially of the races more advanced in civilization, could be understood only by

studying the moral and intellectual conditions under which the less advanced at present exist.

The result of Western contact, whether commercial or philanthropic, were dwelt upon at large, and shown to be so hurtful, that they were the chief (if not the only) external causes of the dying out of the backward peoples. Numerous illustrations in support of this were given. Western civilization, in its relations, past or present, with China, India, Japan, besides other places, was reviewed, and its unfitness was illustrated; in support of which conclusion references were made to and quotations were given from the writings of Mr. A. R. Wallace, Captain R. S. Burton, Mr. Winwood Reade, Lord Elgin, and others.

In conclusion, the author argued that the duty of Western anthropologists to the backward peoples is that, recommended by Auguste Comte, of protection. Anthropologists should urge upon the Western governments the policy of preserving the backward peoples, and of protecting them against the cruel and lawless of whatever colour or race.

Discovery of a Flint-Implement Station in Wishmoor Bottom, near Sandhurst. By Lieut. C. Cooper King, *R.M.A.*

The author described the discovery of several isolated groups of flint flakes in limited areas in Wishmoor Bottom, near Sandhurst, one "find" including a large number of flakes with several cores and two implements of palæolithic type. The marshy deposit with the flints occupies a minor *cul-de-sac* valley; and a small isolated hill in its opening has sheltered the station from the great east and west road line which runs near it. The flint from which the implements were made appears not to be the flint of the neighbourhood, but must have been brought from a distance. It was suggested that the area in which the discoveries were made may have been a small lake at the period of its occupation by an aboriginal race, and the small groups of flints may be the sole remnants of an ancient lake-dwelling.

The Pretended Identification of the English Nation with the "Lost House of Israel." By A. L. Lewis, *M.A.I.*

On the Skeleton of the Red Rocks. By M. Moggridge, *F.G.S., F.R.Hist.S.*

On the seashore two miles east of Mentone is a range of lofty cliffs, called the Rochers Rouges. They are composed of Jurassic limestone, and abound in caverns. A photograph showed their general character; and the cave most to the right, which is 103 feet above the sea, is that in which the skeleton (which has been dignified by several appellations) was discovered recently by Dr. Rivière, who is employed by the French government to make excavations for fossils along this coast (though in fact these rocks are in Italy), and whose skill and perseverance have brought to light many valuable specimens.

This cave, which has been subjected to many previous explorations, at the mouth nine feet deep, was filled up to the modern floor with earth, *angular* stones, flints worked by man, some charcoal, and the remains of diverse animals. As was shown in the photograph, the skeleton was lying upon the left side, in an attitude such as might have been assumed in sleep. It was eight feet below the modern floor at that part of the cave, nine feet from the entrance, lying north and south, and the head was to the south. Eye-teeth of the deer and small shells, both pierced, encircled the skull; possibly they may have ornamented a fillet; many fell off before the photograph was taken. In contact with the body flint instruments had been placed; and a circle or rather oval was formed around by rude stones in juxtaposition. With one end touching the closed teeth, and projecting from the mouth as if that end had been placed within the lips, was a mass of metallic grains (oxide of iron), four inches long and one inch wide, of which a sample was shown. Such substance does not occur in the neighbourhood, and the author knows no parallel

case. May it have been a fetish or charm? The shin-bone is flat, as in the skeletons found by Mr. Busk at Gibraltar.

Passing to the interior, the rock at the bottom descends to a lower level. In those recesses occur the remains of *Ursus spelæus*, *Hyæna spelæa*, Rhinoceros, &c. Thus if the skeleton does not carry us back to the days of the extinct animals (unless the deer may be of an extinct species), it is a very interesting relic of the "Flint Age." It may, however, be asked, How are we to fix the termination of that age? Does it not vary with the approach to civilization of different races? To this day with the Esquimaux that age has not terminated.

The immediate neighbourhood of this cave does, however, afford proof that man *was* contemporaneous with the extinct beasts, as the author showed at Edinburgh, where he stated that at a depth of thirty feet, in breccia (formed of *angular* stones, luted together by carbonate of lime and oxide of iron, and so solid that it could only be worked by blasting), he had himself taken out the remains of *Ursus spelæus* &c. in contact with flints worked by man, which may now be seen in the temporary museum.

The author concluded with testifying to the zeal, talent, and laudable perseverance of Dr. Rivière, the gentleman who discovered this highly interesting skeleton.

On the Ethnological Affinities of the French and English Peoples. By Dr. T. Nicholas, *M.A., F.G.S.*

Having assumed that Britain had been first peopled from Gaul, a fact partly substantiated by Cæsar, the author proceeded to inquire into those changes, or supposed changes, of race-character which various conquests had brought upon both peoples. Having intimated that the Roman occupation of several hundred years had resulted in greater race-admixture on both sides of the Channel than was usually allowed, the author argued, from a rapid glance at the Frankish conquest of Gaul by Clovis, and the second conquest by Pepin and Charlemagne, that they had not very extensively imbued the Gallic population with Frankish blood, and, in like manner, that the parallel conquest of Britain by the Germans, usually known as the Saxon Conquest, had only very partially converted the people of Britain into Anglo-Saxons, except in name. The Britons, instead of having been, according to the popular representation based on the 'De excidio Britanniæ' of the supposititious Gildas, exterminated or bodily expelled the country, had in time coalesced with the invaders and become one people. This was the only way in which seven or eight populous sovereignties could be furnished with subjects in so short a time. Before the descent upon Neustria by Rollo, and the conquest of England by the Danes and Normans, therefore, the Celtic character of the mass of the French people had not been greatly changed, and the people of England were in all probability less German than Celtic. It followed that the term "Anglo-Saxon" could only be applied to the English in the same unscientific way as the term "Franks" (French) was applied to the substantially Gallic inhabitants of Gaul, and always involved a distortion of the truth. The Norman Conquest was achieved by an army presumably more Gallic than Norman, and had therefore only added to the Celtic blood of England; while the Norman conquest of Neustria had affected but a small fraction of the French, and affected that fraction ethnically but very slightly. The conclusion, therefore, from this parallel, as from the other parallels in the history of the two nations, was, that they have continued to partake largely of Celtic blood, although not so largely as in pre-Roman times. The English, less Teutonized than was usually supposed by the Anglian and Jutish incursions, had, during the Danish and Norman periods, been rendered considerably less Celtic than their neighbours across the Channel. The physical characteristics of the French, as determined by Broca, Edwards, and others, and some of their mental and social characteristics, were pointed out as constituting points of difference between them and the English. On the whole, the claims to sympathy and amity which, on ethnological grounds, the two nations had on each other were held by the author to be strong.

Notice of a Silicified Forest in the Rocky Mountains, with an account of a supposed Fossil Chip. By H. ALLEYNE NICHOLSON, *M.D., D.Sc., F.R.S.E., Professor of Natural History in University College, Toronto.*

The object of this communication was to describe two specimens which had recently been presented to the Museum of Toronto University, Canada, by Mr. Worthington of that city. One of the specimens is a large fragment of silicified wood obtained by that gentleman from a fossil forest in the Rocky Mountains. This forest is situated not far from Colorado city, at a supposed height of seven thousand feet above the sea, in the neighbourhood of the mountain known as Pike's Peak, not far from Ute Pass. The forest covers a large area, the trees standing apparently on the margins of an ancient lake. The stumps vary from three to four feet in height, and from ten to twenty feet or more in diameter, and there can be but little doubt as to their being the remains of a forest of the *Sequoia gigantea*, which still lives in California. A similar forest was described by Professor Marsh near Mount St. Helena, the age of which was shown to be later Pliocene; so that there is every probability that the antiquity of the present forest is the same.

Another specimen is one of extreme interest, if only exact details were obtainable as to the circumstances under which it was found. It appears to be one of many specimens which was picked up on the ground close to the stump of one of these large trees; and it presents all the appearances of a fossil *chip* struck from the living tree by the hand of man. The author showed that every particular in this specimen corresponded exactly with what is observable in an ordinary chip cut from a standing tree by an experienced axe-man. This is especially the case with the upper surface of the specimen, which presents a clean obliquely descending face, cutting across the fibres of the wood, and even exhibiting the unequal shrinking of the different layers of wood, which is invariably observable whenever soft wood is divided in this manner by a sharp instrument. Actual chips in every respect undistinguishable from this specimen could be obtained anywhere in the backwoods in Canada; and it seems impossible to doubt that it really was a chip cut from one of these ancient trees. The chief difficulty in the way of this view is the fact that the surfaces of incision are too clean to have been made by any thing except a metal implement. It was impossible, however, to determine from the data in hand what might be the date at which this fossil was silicified.

On some Evidences suggestive of a Common Migration from the East, shown by Archaic Remains in America and Britain. By JOHN S. PHENÉ, *F.S.A., F.G.S., F.R.G.S., F.R.I.B.A.*

The author first referred to a paper read by him last year at the Meeting held at Edinburgh, in which he had drawn attention to some remarkable mounds in North Britain, which he considered were identical with the serpent and alligator mounds of America. He stated that since that Meeting he had opened the most perfect of these British mounds, and with very satisfactory and interesting results; but as the particulars of the investigation had been published both by himself and also by Miss Constance F. Gordon Cumming (in 'Good Words,' with an illustration), he should pass on to other matter.

He then showed from drawings by several artists, including the names of Mr. C. J. Lewis and Miss Gordon Cumming, by photographs, and by different models taken by Mr. Mortimer Evans, C.E., F.G.S., of Glasgow, the peculiar formation of the mound.

He pointed out various difficulties he had met with in coming to an accurate decision about the mound, but how, finally, he found, on reducing it to scale and taking the various levels, that it agreed almost entirely with the Egyptian Uræus and the Phœnician Serpent deity, each of which is represented in relics now extant as in the precise position of the form of the mound, and each with the solar disk at its head, which is found to correspond exactly with the cairn formerly described as the head, but which is now found to be in the position of resting upon it, assuming the figure were placed vertically instead of horizontally.

The author next proceeded to show that his observations on this point also explained the only ambiguity in the case of the great American serpent mound at Ohio, which he also argued is surmounted by the solar orb, thereby agreeing with the Egyptian, Phœnician, and, as he claims, British representations also.

He then illustrated his subject by a great many examples of customs in the mode of constructing this class of monuments common to several countries, especially modes of excavation, carving into form, and erection, which he found agreed in each case in Egypt, America, and Britain; and from these he argued a common origin, custom, and migration. He quoted Mr. Fergusson to show that the theory he advanced was the most probable course by which America could have been visited by the mound-builders of the east of Europe, and who might also with equal reason have spread to Britain.

He then quoted a number of authorities to show that the words OB, meaning serpent, and ON, meaning sun, represented the sun and serpent deity commonly worshipped in Egypt and Phœnicia; that the same word, with the addition of the letter I, is found in Africa: OBION and OBONI both represented serpent and solar deities which were worshipped by some tribes in a visible and sensual manner and by some in a spiritual sense. He showed how rare places with these component names are—one only in Europe (Britain excepted), four or five in Asia, where the worship of the sun and serpent still continues, those already quoted in Africa, and one only in America directly*; but he proceeded to show that some of the American names in the districts of the ancient mounds assimilated very nearly to these, making allowances for no greater variation than had taken place in the form of names in their transmission from Greece to Rome, and concluded his argument by claiming for Oban (the town near where the Argyllshire mound is) the name of the place of the *serpent* and *solar deity*, AB-ON or OB-AN, which he quoted authorities to show were used indifferently, as EBOE and OBOE are in Africa having that meaning—pointing out also that the Israelites called their first encampment, after the making of the brazen serpent, OBOTH.

Reference was made to some Egyptian representations of taking human life by official power as shown in the illustrations, in which the solar serpent deity or Uræus figures as an authority for the act; and the author stated that since his discovery of the mound a Gaelic tradition had been put before him, which the natives state belongs to this mound in particular, and which identifies it as a place of public execution in the early British or Druidical times. The Hindu mythology records a similar serpent mound produced by Krishna; but in this case the serpent was said to be living, although shaped almost exactly like the Argyllshire mound; but it was remarkable that into the head of this serpent people and animals went with Krishna for refuge: this the author took to mean self-immolation and the satisfaction arising from dedication to the deity; and finally quoted Mr. Fergusson to show that the principal essential wanting, in his opinion, to constitute the British monuments places of sacrifice was present in the case of the Argyllshire mound.

On the Skulls obtained in Canon Greenwell's Excavations. *By* Professor Rolleston, *M.D., F.R.S.*

Professor Rolleston gave an account of a large number of detailed measurements of the skulls obtained by Canon Greenwell in his excavations, and now presented by him to the Oxford University Museum. He observed that his examination of the skulls had been carried on without any reference, in most cases, and without any knowledge in many, of their archæological surroundings. Two types of skull, the same two as had been described by Dr. Thurnam in his well-known papers, were to be found in the series submitted to him. Skulls of the dolichocephalic type were frequently, however, found to bear the same label as skulls of the brachycephalic, and might be presumed therefore to have come from the same barrows. If it should turn out to be the fact that these two kinds of skull had been found with the same archæological surroundings, this would be a different

* Since reading this paper, the author finds the name OBION was applied to a river in America on the route taken by the ancient mound-builders.

condition of things from that which had been described by the trustworthy author already referred to as existing in Wiltshire, and would have to be explained either as being the result of an intermixture of the two races peacefully, or as the manifestation of a tendency to variation not unparallelled even in wild tribes. The form of cranium which Retzius had called the "Common Celtic form" (see 'Journal of Anatomy,' vol. iii. p. 254, 1868) was almost entirely absent in this series. The same remarks applied to the form of cranium known as the "Borris Type" (see Huxley in 'Prehistoric Remains of Caithness,' p. 128).

On the Weddo of Ceylon. *By* Professor ROLLESTON, *M.D.*, *F.R.S.*

Professor Rolleston exhibited ten photographs of the Jungle Weddo, taken by B. F. Hartshorne, Esq., as also three skulls of the same tribe procured by the same gentleman, and some skulls of certain Kolarian tribes procured by H. Duthoit, Esq., of Mirzapore, and exhibited for the sake of comparison with those of the Ceylon aborigines. There was no doubt about the genuineness of the three Weddo skulls; yet one of the three was as markedly brachycephalic (the cephalic index being 81) as the others, or as Weddo skulls usually, were dolichocephalic. The cephalic indices in the two other skulls procured from the district of the Jungle Weddo, a tribe now numbering, in all probability, little over 100 persons, were 70 and 76. In three other Weddo skulls, two of which had been obtained by Lieutenant Perkins for Canon Greenwell, and the third had been presented by Mr. Sabonnadiere to the Oxford University Museum, the cephalic indices were respectively 72, 68, and 64. The cubic capacity in each of the two dolichocephalic crania sent by Mr. Hartshorne was 85·25 cubic inches and 80 cubic inches respectively; the cubic capacity of the single brachycephalic specimen was, approximatively, 69 cubic inches. It was of importance to note that synostosis could have had nothing to do with the bringing about of the aberrances of the brachycephalic Weddo cranium; for the coronal suture was open whilst the sagittal was obliterated, the very condition which, if the shape of the skull had ruled the shape of the brain instead of the reverse, would have produced dolichocephaly. The presence of parietal occipital flattening on the left side (a deformity unintentionally produced during early life by the mode of carrying the infant) was also noteworthy as being rarely observed except in brachycephalous skulls. With reference to the large question of the affinities of the Dravidian races of Continental India to the Weddo of Ceylon, Professor Rolleston referred to the papers on Indian Ethnology published in the 'Journal of the Ethnological Society,' July 1869, by Sir Walter Elliot, George Campbell, Esq., Dr. Campbell, and others.

Religious Cairns of the Himalayan Region. *By* R. B. SHAW.

All through the Himalayan region, the slopes of the Dhaola Dhar inhabited by high-caste Hindus, on the barren plains and in the rocky valleys of Tibet among the Buddhist hill-men, and in the gorges of the Kuenlun Mountains until they debouch upon the plains of Turkistan, there are to be found *cairns* of a similar description and placed in similar situations. The crests of passes, the summits of isolated points of rock, or any other place from which a remarkable view is obtained of a mighty peak or a terrific precipice are the positions they generally occupy. Throughout the whole of this region they are adorned in a similar way, being stuck over with tall sticks, from which wave rags and flags and tails of horse or yâk, the votive offerings of passers by.

When we find that these cairns, similar in character and similar in position, are to be found throughout regions inhabited by men of *three different races* and *three different religions*, who each ascribe to them a different origin and a different purpose, the importance of the subject is evident. No one who has observed carefully the facts on the spot is likely to doubt that the monuments in the several districts in question were all erected with the same intent, whatever that was. The position of most of them forbids the supposition that they can have been landmarks or tombs. The labour bestowed in fetching the stones, often from a long distance,

shows that they had some serious purpose. But the author can conceive of no common purpose which can have induced men of such dissimilar religions as the Hindu, the Buddhist, and the Mussulman to erect similar monuments.

One supposition suggested itself, which was that these cairns are monuments of the Buddhist faith, which is the only one known to have ever prevailed over the entire region of Tibet and Turkistan. But there is this objection, that although similar monuments are found in the Buddhist districts, yet they exist in opposition to the Buddhist priesthood, who will have nothing to do with them, and thus are not likely to have implanted them in other districts.

The author thinks that he recognized in these cairns the remains of an early kind of worship (anterior to Buddhism) which undoubtedly existed at one time throughout these hills, and which perhaps overspread the entire region between India and Turkistan. There are traces of the adoration of local deities all over this region. In the outer Himalaya such sacred spots are numerous, and occupy exactly similar positions with the "Lhato" of Tibet and the "Mazars" of the Kuenlun Mountains, viz. eminences and remarkable places. The influence of these divinities is not supposed to extend beyond a few hundred yards from their local habitation, which is marked also by red paint, rusty iron tridents, and fluttering rags. Outside the magic circle the worshippers will often mock at the object of their adoration, but within it they are all devotion. These supernatural beings are generally called after "Dévi," the Hindu goddess of destruction, who seems to be indefinitely subdivided or multiplied by her worshippers in the hills, contrary, as the author was informed, to the orthodox practice of pure Hinduism. They talk of this Dévi and that Dévi as Italians do of the Madonna of such or such a place, honouring some more than others, as Louis XI. was wont to do in the familiar pages of Walter Scott.

Besides the Dévis there are numerous other local worships in the Hindu part of the Himalaya; and, with a change in the names, we have just the same in Tibet and in Eastern Turkistan. Moreover at the boundaries or the neutral ground between the three religions we find the very same cairns or symbols of local influences worshipped in common by the followers of both the neighbouring Faiths, who bestow each their own designation on the same object.

Those monuments and localities which the Hindus associate with the name of "Dévi," "Indur," &c. are in Tibet called "Lhato" (*Lha* meaning a god or supernatural power, as in Lhassa, which means "the abode of the gods").

In the Mussulman districts, on the other hand, these cairns are known by the name of "Mazar," which means the shrine or tomb of a saint; and such is the origin they ascribe to them, regardless of the improbability of so many holy men retiring to the tops of almost inaccessible rocks to be buried.

Several times the author found abandoned cairns in most desolate and unfrequented spots. They were not decked out, like the others, with flags and rags at the ends of poles, but had a neglected look, and were half covered with drifted sand.

The author's wild guides, the Kirgling tribesmen, refused to recognize these cairns as "Mazars," though in every respect resembling those which they revered so much. They told him that these mounds had been raised by a race who frequented that country long before *they* had migrated into it. In fact they had no certain tradition; and they are but new comers themselves.

Some Yarkandis who were questioned, stated that these were "Kafir" or "infidel" monuments, and that similar ones were to be found throughout Eastern Turkistan but not in Western.

Again, the Tibetans who accompanied the author into Turkistan immediately identified both the honoured and also the abandoned "Mazars" as their own country's "Lhato." One in particular attracted their attention. It was in a level part of the upper Karakash valley, and there seemed to be no reason for its existence there; until at last one of them spied out a remarkable peak in the distance, which first came into sight at the point where the cairn was erected. This peak had a triple point; and this, the author was informed, would in Tibet have been quite sufficient to ensure even the most distant view of such a summit the honour of being marked by a Lhato; for 3 is a mystic number.

If these may all be referred back to a primitive religion consisting of the worship

of mountain-demons (including in the Himalaya the veneration of tree- and water-demons, other *natural* divinities of which many traces remain), then the three newer religions which have since occupied this region, the Hindu, the Buddhist and the Mussulman, have each adopted this part of the old belief and assimilated it into its own system. It is curious to see their different treatment of the same belief. The Hindu gives the most supernatural turn to it. All these spots, however numerous or distant, have become the special habitation of one and the same divinity of the Hindu Pantheon, who by the common people is conceived as being entirely separate and distinct deities. The Mussulman gives a purely human and ordinary explanation: certain holy men have died and been buried there. The Buddhist, on the other hand, leaves the old superstition alone, giving it a wide berth. The country people pay their devotions to these cairn-deities to ward off their displeasure from their fields and cattle; but the Lama gives them no place in his books or in his worship. His veneration is reserved for the deified saints of Buddhism, following each in his proper rank after the great Sakya-Moonee. It is true the Lamas sometimes help their superstitious countrymen with charms against the power of these cairn-deities and of other evil spirits, such as the serpent demon; but this is probably illicit connivance.

The fact is that all over these mountains, under one excuse or another, the country people propitiate certain localized influences, which are supposed to be confined within certain limits. For instance, the inhabitants of an hamlet are not supposed to pay any attention to the object of their neighbours' fear or veneration, unless they place themselves locally within its power. The Mussulman bestows the least superstition on them, and the Buddhist gives them the smallest amount of recognition and sanction.

The author mentioned a ceremony which he witnessed in Ladâk, and which is probably a relic of the supposed ante-Buddhist worship. A certain female deity or demon is supposed to be revealed each year at the village of Shé, embodied in one or other of the members of a certain family who hold this heritage. The individual chosen by the goddess on this occasion was dressed out in fantastic though costly garments with a regal tiara on his head, and when first seen was dancing in a weird fashion on the lofty battlements of one of the Buddhist monasteries, which are often so picturesquely perched on the top of a steep cliff. On this dizzy eminence the goddess danced in human form, while in a little green plain below a dense crowd watched every motion with upturned faces. At last the mystic personage descended. Making his way through the crowd, he approached a spring of water which bubbles up in the midst of the little plain, converting half of it into a swamp, which can only be crossed by a stone causeway. This causeway terminates at the spring, and on its extremity stands one of these stone erections called Lhato, but of a more finished character than those before described. On the Lhato a dish of burning incense was placed; and as the inspired mortal paced up and down in its fumes, many of the crowd approached one by one and asked him questions regarding futurity, which by the power of the goddess he was supposed capable of answering correctly.

Now in all this there was one noticeable fact. Although in Tibet the Lamas usually form as large a part of a crowd as monks and priests used to do in Naples and Rome, yet on this occasion not a single Lama was visible. Not one could be found to sanction by his presence the worship of this local deity.

The author has witnessed almost similar devil-dances amongst the Hindu hill-men of the outer Himalaya. There, however, more than one person takes part in the ceremony, which is generally performed before the rude shrine of one of these local deities or of the snake god the Nâg. A sudden Bacchic fury seems to seize individual members of the crowd, who rush forward, trembling in every limb, and with glaring eyes, and baring the upper part of their body as they go, they dance round, lashing their backs with a sort of iron cat-o'-nine tails, which is handed round from one to the other. In this state they are consulted by the standers by, who receive their words as oracles. Sometimes ten or a dozen of these devotees are hopping around the circle at the same moment. Their excitement is undoubtedly accompanied with something resembling an hysterical affection, which leaves them faint and exhausted. When they reach this stage, their friends stand

by to receive them while they take a short run and jump into their arms; for it seems the spirit cannot leave them while their feet are on the ground.

The author has known one of these devotees writhe and roll himself along the ground to imitate the motion of a snake, that being the divinity in whose honour he was performing.

On Rubbings from St. Patrick's Chair, Co. Mayo, Ireland. By R. S. Symes, *F.G.S.*

On the Relation of the Parish Boundaries in the South-east of England to great Physical Features, particularly to the Chalk Escarpment. By W. Topley, *F.G.S., Geological Survey of England and Wales.*

The author first drew attention to the fact that the outcroppings of various strata are marked by the occurrence thereon of numerous villages, whilst some neighbouring formations have none. Good water, a soil fit for arable culture, and a dry site were usually found in these situations. The chalk area of England was described, and it was shown that everywhere along the foot of the "chalk escarpment" a line of villages occurred. The parishes belonging to these villages in nearly every case ascend the escarpment, taking in more or less of the plateau above; it is very rare, indeed, to find a village on the chalk plateau sending its parish down the escarpment.

The author then described in greater detail the physical geography of the Wealden area, and the arrangement of the villages and their parishes along its border. Everywhere below the chalk escarpment there is a line of villages, the parishes of which *ascend the escarpment*, whilst the villages above or on the chalk rarely send their parishes down the escarpment. Of the parishes around the Wealden border, 119 conform to the rule laid down, whilst the exceptions number only six.

The Lower Greensand forms a second and inner plateau and escarpment around the Weald. Along this formation there are numerous villages; but it is remarkable that the behaviour of their parishes to the Lower-Greensand escarpment is just the reverse of that observed with the chalk; for here the parishes of villages upon the plateau go down the escarpment, and comparatively few of the villages on the flat below (or the Weald Clay) send their parishes up the escarpment. These and other points discussed were illustrated by sections and large maps, in which each parish was separately coloured.

The author contended that in the facts here described we have evidence of the order in which the country was settled. Much of the chalk area must always have been, as now, open land; over this area we find numerous Celtic remains. The first settlement would take place along the foot of the chalk escarpment; and in the division of land resulting from these, some area of down-land would be taken in in one direction, and wood-land or pasture in the other direction. There would thus be a line of settlements with their appropriated lands all along the foot of the chalk escarpments. Later settlements took place along the Lower-Greensand area; these would find the land all occupied in one direction, towards the chalk, but in the other direction, or towards the great Wealden forest, the land was all unappropriated. In this direction, *down the escarpment*, they therefore extended. The evidences of these later settlements may be found in local names.

The date of our parishes is for the most part unknown. The boundaries of those wholly within the Weald were not settled till the century after the Conquest; these were the latest formed. The earliest, or those along the chalk escarpment, would appear from their names to be chiefly English.

The author concluded his paper as follows:—"In speaking as I have done of the probable relative date of the various settlements and their parishes, I of course do not mean that our *parishes* date so far back. The date at which most of our parishes were formed, and even whether they were originally civil or ecclesiastical divisions, is all involved in doubt; and I do not pretend that this investigation throws much light directly upon the subject. Still, I think, it does give a little. If parishes were ever formally planned out, it seems in the highest degree unlikely

that such striking agreement with the physical features as I have shown to exist should occur. Probably such features would be altogether ignored; or if taken into consideration would be seized upon as *boundaries*. One could scarcely desire a more striking physical feature for a boundary than the chalk escarpment; but we have seen that it is only in rare cases that this forms the boundary of a parish; generally it is well within the parish, which stretches up and often far beyond it. The boundaries *cross* the escarpment, in nine cases out of ten at right angles to it. So again with the Lower-Greensand escarpment; although in its relation to the parishes it acts exactly the reverse of the chalk escarpment, yet they agree in rarely forming parish boundaries. To this it may be answered that, whatever the origin of parishes, whether civil or ecclesiastical, whether by grouping or subdividing divisions of land previously existing, regard would necessarily be had to the shape and extent of those divisions. This, I think, must have been the case; and considerations advanced in this paper lead us to infer that whatever may have been the origin of manors or parishes as such, they both depend upon still older divisions of the land, and that these were not formed by the arbitrary act of church or king, but resulted necessarily from the great physical features of the country."

The Origin of Serpent-Worship. By C. STANILAND WAKE, *M.A.I.*

After referring to various facts showing the existence of serpent-worship in many different parts of the world, the paper proceeded to consider the several ideas associated with the serpent among ancient and modern peoples. One of its chief characteristics was its power over the wind and rain; another was its connexion with health and good fortune, in which character it was the Agathodæmon. The serpent was also the symbol of life or immortality, as well as of wisdom. It was then shown that that animal was viewed by many uncultured peoples as the re-embodiment of a deceased ancestor, and that descent was actually traced by the Mexicans and various other peoples from a serpent. The serpent superstition thus becomes a phase of ancestor-worship, the superior wisdom and power ascribed to the denizens of the invisible world being assigned also to their animal representatives. When the simple idea of a spirit ancestor was transformed into that of the Great Spirit, the father of the race, the attributes of the serpent would be enlarged, and it would be thought to have power over the rain and the hurricane. Being thus transformed to the atmosphere, the serpent would come to be associated with nature, or solar-worship. Hence we find that the sun was not only a serpent god, but also the divine ancestor or benefactor of mankind. Seth, the traditional divine ancestor of the Semites, was the serpent sun-god, the Agathodæmon; and various facts were cited to establish that the legendary ancestor of the people classed together as Adamites was thought to possess the same character. It would appear to follow from the facts mentioned in the paper that serpent-worship, as a developed religious system, originated in Central Asia, the home of the great Scythic stock, from which the civilized races of the historical period sprung, and that the descendants of the legendary founder of that stock, the Adamites, were in a special sense serpent-worshippers.

The Rev. H. H. WINWOOD, M.A., F.G.S., exhibited some Flint Implements from South Africa.

GEOGRAPHY.

Address by FRANCIS GALTON, *F.R.S., President of the Section.*

THE functions of the several Sections of the British Association differ from those of other Institutions which pursue corresponding branches of science. We who compose this Section are not simply a Geographical Society, meeting in a hospitable and important provincial town, but we have a distinct individuality of

our own. We have purposes to fulfil, which are not easily to be fulfilled elsewhere; and, on the other hand, there are many functions performed by Geographical Societies which we could not attempt without certain failure. Our peculiarities lie in the brief duration of our existence, combined with extraordinary opportunities for ventilating new ideas and plans, and of promoting the success of those that deserve to succeed. We are constituents of a great scientific organization, which enables us to secure the attention of representatives of all branches of science to any projects in which we are engaged; and if those projects have enough merit to earn their deliberate approval, they are sure of the hearty and powerful support of the whole British Association.

These considerations indicate the class of subjects to which our brief existence may be devoted with most profit. They are such as may lead to a definite proposal being made by the Committee of our Section for the aid of the Association generally; and there are others, of high popular interest, which cannot be thoroughly discussed except by a mixed assemblage, which includes persons who are keen critics though not pure geographers, and who have some wholesome irreverence for what Lord Bacon would have called "the idols of the geographical den."

We may congratulate ourselves that many excellent memoirs will be submitted to us, which fulfil one or other of these conditions. They will come before us in due order, and it is needless that I should occupy your attention by imperfect anticipations of them. But I must say that their variety testifies to the abundance of the objects of geographical pursuit, other than exploration. There is no reason to fear that the most interesting occupation of geographers will be gone when the main features of all the world are known: on the contrary, it is to be desired, in the interests of the living pursuit of our science, that the primary facts should be well ascertained, in order that geographers may have adequate materials, and more leisure to devote themselves to principles and relations. I look forward with eagerness to the growth of Geography as a science, in the usually accepted sense of that word; for its problems are as numerous, as interesting, and as intricate as those of any other. The configuration of every land, its soil, its vegetable covering, its rivers, its climate, its animal and human inhabitants act and react upon one another. It is the highest problem of Geography to analyze their correlations, and to sift the casual from the essential. The more accurately the crude facts are known, the more surely will induction proceed, the further will it go, and, as the analogy of other sciences assures us, the interest of its results will in no way diminish.

As a comparatively simple instance of this, I would mention the mutual effects of climate and vegetation, on which we are at present very imperfectly informed, though I hope we shall learn much that is new and valuable during this Meeting. Certain general facts are familiar to us—namely, that rain falling upon a barren country drains away immediately. It ravages the hill-slopes, rushes in torrents over the plains, and rapidly finds its way to the sea, either by rivers or by subterranean watercourses, leaving the land unrefreshed and unproductive. On the other hand, if a mantle of forest be nursed into existence, the effects of each rainfall are far less sudden and transient. The water has to soak through much vegetation and humus before it is free to run over the surface; and when it does so, the rapidity of its course is checked by the stems of the vegetation: consequently the rain-supplies are held back and stored by the action of the forest, and the climate among the trees becomes more equable and humid. We also are familiar with the large differences between the heat-radiating power of the forest and of the desert, also between the amount of their evaporation; but we have no accurate knowledge of any of these data. Still less do we know about the influences of forest and desert on the rate of passage, or upon the horizontality, of the water-laden winds from the sea over the surface of the land; indeed I am not aware that this subject has ever been considered, although it is an essential element in our problem. If we were thoroughly well informed on the matters about which I have been speaking, we might attempt to calculate the precise difference of climate under such and such conditions of desert and of forest, and the class of experiences whence our data were derived would themselves furnish tests of the correctness of our computations. This will serve as an example of what I consider to be the

geographical problems of the future; it is also an instance of the power of man over the phenomena of nature. He is not always a mere looker-on and a passive recipient of her favours and slights; but he has power, in some degree, to control her processes, even when they are working on the largest scale. The effects of human agency on the aspect of the earth would be noticeable to an observer far removed from it. Even were he as distant as the moon is, he could see them; for the colour of the surface of the land would have greatly varied during historic times, and in some places the quantity and the drift of cloud would have perceptibly changed. It is no trifling fact in the physical geography of the globe that vast regions to the east of the Mediterranean, and broad tracts to the south of it, should have been changed from a state of verdure to one of aridity, and that immense European forests should have been felled.

We are beginning to look on our heritage of the earth much as a youth might look upon a large ancestral possession, long allowed to run waste, visited recently by him for the first time, whose boundaries he was learning, and whose capabilities he was beginning to appreciate. There are tracts in Africa, Australia, and at the Poles not yet accessible to geographers, and wonders may be contained in them; but the region of the absolutely unknown is narrowing, and the career of the explorer, though still brilliant, is inevitably coming to an end. The geographical work of the future is to obtain a truer knowledge of the world: I do not mean by accumulating masses of petty details, which subserve no common end, but by just and clear generalizations. We want to know all that constitutes the individuality, so to speak, of every geographical district, and to define and illustrate it in a way easily to be understood; and we have to use that knowledge to show how the efforts of our human race may best conform to the geographical conditions of the stage on which we live and labour.

I trust it will not be thought unprofitable, on an occasion like this, to have paused for a while, looking earnestly towards the future of our science, in order to refresh our eyes with a sight of the distant land to which we are bound, and to satisfy ourselves that our present efforts lead in a right direction.

The work immediately before us is full of details, and now claims your attention. There is much to be done and discussed in this room, and I am chary of wasting time by an address on general topics. It will be more profitable that I should lay before you two projects of my own about certain maps, which it is desirable that others than pure geographers should consider, and on which I shall hope to hear the opinions of my colleagues in the Committee-room of this Section.

They both refer to the Ordnance Maps of this country, and the first of them to the complete series, well known to geographers, that are published on the scale of one inch to a mile. It is on these alone that I am about to speak; for though many of my remarks will be applicable more or less to the other Government map publications, I think it better not to allude to them in direct terms, to avoid distracting attention by qualifications and exceptions.

English geographers are justly proud of these Ordnance Maps of their country, whose accuracy and hill-shading are unsurpassed elsewhere, though the maps do not fulfil, in all particulars, our legitimate desires. I shall not speak here of the absence from the coast-maps of the sea *data*, such as the depth and character of the bed of the sea, its currents and its tides (although these are determined and published by another Department of the Government, namely the Admiralty), neither shall I speak of the want of a more frequent revision of the sheets, but shall confine myself to what appear to be serious, though easily remediable, defects in the form and manner of their publication. It is much to be regretted that these beautiful and cheap maps are not more accessible. They are rarely to be found even in the principal booksellers' shops of important country towns, and I have never observed one on the bookstall of a railway-station. Many educated persons seldom, if ever, see them; they are almost unknown to the middle and lower classes; and thus an important work, made at the expense of the public, is practically unavailable to a large majority of those interested in it, who, when they want a local map, are driven to use a common and inferior one out of those which have the command of the market. I am bound to add that this evil is not peculiar to our country, but is felt almost as strongly abroad, especially in respect to the Government maps of

France. I account for it by two principal reasons. The first is, that the maps are always printed on stiff paper, which makes them cumbrous and unfit for immediate use: it requires large portfolios or drawers to keep them smooth, clean, and in separate sets, and an unusually large table to lay them out side by side, to examine them comfortably and to select what is wanted. These conditions do not exist on the crowded counter of an ordinary bookseller's shop, where it is impossible to handle them without risk of injury, and without the certainty of incommoding other customers. Moreover, their stiffness and size, even when published in quarter sheets, make them most inconvenient to the purchaser. Either he has to send them to be mounted in a substantial and therefore costly manner, or he must carry a roll home with him, and cut off the broad ornamental borders and divide the sheet into compartments suitable for the pocket, which, to say the least, is a troublesome operation to perform with neatness. The other of the two reasons why the maps are rarely offered for sale is that the agents for their publication are themselves map-makers, and therefore competitors, and it is not to be expected of human nature that they should push the sale of maps adversely, in however small a degree, to their own interests.

The remedy I shall propose for the consideration of the Committee of this Section is, to memorialize Government to cause an issue of the maps to be made in quarter sheets on thin paper, and to be sold folded into a pocket size, like the county maps seen at every railway-station, each having a portion of an index-map impressed on its outside, to show its contents and those of the neighbouring sheets, as well as their distinguishing numbers. Also I would ask that they should be sold at every "Head Post-office" in the United Kingdom. There are about seven hundred of these offices, and each might keep nine adjacent quarter sheets in stock, the one in which it was situated being the centre of the nine. An index-map of the whole survey might be procurable at each of these post-offices, and, by prepayment, any map not kept in stock might be ordered at any one of them, and received in the ordinary course of the post. This is no large undertaking that I have proposed. The price of a quarter sheet in its present form, which is more costly than what I ask for, used to be sold for only sixpence; therefore the single complete set of nine sheets for each office has a value of not more than four shillings and sixpence, and for all the seven hundred Head Post-offices of not more than £160.

I believe that these simple reforms would be an immense public boon, by enabling any one to buy a beautiful and accurate pocket-map of the district in which he resides for only sixpence, and without any trouble. They would certainly increase the sale of Government maps to a great extent; they would cause the sympathies of the people and of their representatives in Parliament to be enlisted on the side of the Survey, and they would probably be imitated by continental nations.

It has often been objected to any attempt to increase the sale of Government maps, that the State ought not to interfere with private enterprise. I confess myself unable to see the applicability of that saying. It would be an argument against making Ordnance Maps at all: but the nation has deliberately chosen to undertake that work, on the ground that no private enterprise could accomplish it satisfactorily; and, having done so, I cannot understand why it should restrict the sale of its own work, in order to give a fictitious protection to certain individuals, against the interests of the public. It seems to me to be a backward step in political economy, and one that has resulted in our getting, not the beautiful maps for which we, as taxpayers, have paid, but copies or reductions of them, not cheaper than the original, and of very inferior workmanship and accuracy.

So much for the first of the two projects which I propose to bring before the consideration of the Committee of this Section. It is convenient that I should preface my second one with a few remarks on colour-printing, its bearing on the so-called "bird's-eye views," and its recent application to cartography. Colour-printing is an art which has made great advances in recent years, as may be seen by the specimens struck off in the presence of visitors to the present International Exhibition. One of these receives no less than twenty-four consecutive impressions, each of a different colour from a different stone. This facility of multiplying coloured drawings will probably lead to a closer union than heretofore between geography and art. There is no reason now why "bird's-eye views" of large tracts

of country should not be delicately drawn, accurately coloured, and cheaply produced. We all know what a geographical revelation is contained in a clear view from a mountain top, and we also know that there was an immense demand for the curiously coarse bird's-eye views which were published during recent wars, because, even such as they, are capable of furnishing a more pictorial idea of the geography of a country than any map. It is therefore to be hoped that the art of designing the so-called "bird's-eye views" may become studied, and that real artists should engage in it. Such views of the environs of London would form very interesting and, it might be, very artistic pictures.

The advance of colour-printing has already influenced cartography in foreign countries; and it is right that it should do so, for a black and white map is but a symbol—it can never be a representation of the many-coloured aspects of Nature. The Governments of Belgium, Russia, Austria, and many other countries have already issued coloured maps; but none have made further advance than the Dutch, whose maps of Java are printed with apparently more than ten different colours, and succeed in giving a vivid idea of the state of cultivation in that country.

I now beg to direct your attention to the following point. It is found that the practice of printing maps in more than one colour has an incidental advantage of a most welcome kind, namely, that it admits of an easy revision, even of the most beautifully executed maps, for the following reason. The hill-work, in which the delicacy of execution lies, is drawn on a separate plate, having perhaps been photographically reduced; this has never to be touched, because the hills are permanent. It is on another plate, which contains nothing else but the road-work, where the corrections have to be made; and to do that is a very simple matter. I understand that the Ordnance Survey Office has favourably considered the propriety of printing at some future time an edition of the one-inch maps on this principle, and at least in two colours—the one for the hills and the other for the roads.

This being stated, I will now proceed to mention my second proposal.

Recollecting what I have urged about the feasibility of largely increasing the accessibility and the sale of Government maps, by publishing them in a pocket form and selling them at the Head Post-offices, it seems to me a reasonable question for the Committee of this Section to consider whether Government might not be memorialized to consider the propriety of undertaking a *reduced* Ordnance Map of the country, to serve as an accurate route-map and to fulfil the demand to which the coarse county maps, which are so largely sold, are a sufficient testimony. The scale of the reduced Government Map of France corresponds to what I have in view; it is one of 5 miles to an inch, within a trifle ($\frac{1}{320000}$ of Nature), which is just large enough to show every lane and footpath. Of course it would be a somewhat costly undertaking to make such a map, but much less so than it might, at first sight, appear. Its area would be only one twenty-fifth that of the ordinary Ordnance Map, and the hill-work of the latter might perhaps be photographically reduced and rendered available at once. The desirability of maps such as these, accurately executed and periodically revised, is undoubted; while it seems impossible that private enterprise should supply them except at a prohibitive cost, because private publishers are necessarily saddled with the cost of re-obtaining much of what the Ordnance Survey Office has already in hand for existing purposes. A Government Department has unrivalled facilities for obtaining a knowledge of every alteration in roads, paths, and boundaries of commons, and Government also possesses an organized system in the post-offices fitted to undertake their sale. The production of an accurate route-map seems a natural corollary to that of the larger Ordnance Maps, and has been considered to be so by many Continental Governments.

I therefore intend to propose to the Committee of this Section to consider the propriety of memorializing Government to cause inquiries to be made as to the cost of construction, and the probability of a remunerative sale, of maps such as those I have described; and, if the results are satisfactory, to undertake the construction of a reduced Ordnance Map, on the same scale as that of France, to be printed in colours and frequently revised.

These, then, are the two projects to which I alluded—the one to secure the sale

of one-inch Ordnance Maps, on paper folded into a pocket form, to be sold at the Head Post-offices of the United Kingdom, 700 or thereabouts in number, each office keeping in stock the maps of the district in which it is situated; and the other to obtain a reduced Ordnance Map of the kingdom, on the scale of about 5 miles to an inch, to fulfil all the purposes of a road-map, and to be sold throughout the country at the post-offices, in the way I have just described.

I will now conclude my address, having sufficiently taxed your patience, and beg you to join with me in welcoming, with your best attention, the eminent Geographers whose communications are about to be submitted to your notice.

The Euphrates-Valley Route to India. By W. P. Andrew.

In the opening portion of his paper the author dilated upon the many noble objects which the proposed railway to India, *viâ* the Euphrates Valley, would subserve. It would inevitably entail the colonization and civilizatian of the great valleys of the Euphrates and Tigris, restore the old and renowned productiveness of Mesopotamia, and resuscitate in modern shape Babylon, Nineveh, and Ctesiphon. He argued that no direct route to India, amongst the many which had been proposed, combined so many advantages as the ancient route of the Euphrates. It is the shortest and the cheapest, both for constructing and working a railway,—so free from engineering difficulties, that it appears as though designed by nature for the highway of nations between the East and the West; it is the most surely defensible by England, both its termini being on the open sea, and the most likely to prove remunerative. The other routes proposed, such as those from places on the Black Sea, were open to the fatal objection that while they would be of the greatest service to Russia, they would be beyond the control of Great Britain; they were besides excluded from practical consideration by the engineering difficulties they involved. These conclusions had been demonstrated by many eminent witnesses examined before the recent Select Committee of the House of Commons. The author admitted the value of a continuous line from Constantinople to India, but believed it to be too vast a project to be at present undertaken. The moderate scheme which he advocated was a line 900 miles in length, from the Gulf of Scanderoon, *viâ* the *right* bank of the Euphrates, to Kowait, in the north-western corner of the Persian Gulf. Should it be found desirable hereafter to construct a through line to India, this portion would form a ready-made and considerable section of it. It was precisely that portion of the route between Constantinople and India from which the greatest benefit would be derived by the substitution of railway for sea transit, whether regard be had to the rate of speed or the economy with which the traffic might be worked. Both the proposed termini possess all the requisites of first-class harbours; and the line, on leaving Alexandretta, would run to Aleppo, and along the Euphrates, by way of Annah, Hit, Kerbela, Nedjef, Somowha, and Sheikh el Shuyukh, to Kowait. The Euphrates would not be crossed, and the line would have the strategic advantage of two great rivers being interposed between it and an advancing enemy on the flank on which there would be the greatest likelihood of danger arising. The cost of the railway was estimated at £9,000,000 sterling. The advantages of the proposed railway to England would be the possession of an alternative route to India and the saving of nearly 1000 miles in linear distance.

On the Orography of the Chain of the Great Atlas. By John Ball, *F.R.S.*, *F.L.S.*

The representations of the chain of the Great Atlas given on the most modern maps show how very vague and incomplete our knowledge still is. They agree in very little beyond the fact that high mountains extend in a nearly direct line from the west coast, where they approach the Atlantic, near Agadir, in about 30° 30′ N. lat., for about 500 miles inland, where they subside at no great distance from the frontier of Algeria about the parallel of 33° 30′.

All but the most recent maps indicate a single range similar in general character

to that of the Pyrenees; while in these we find represented two nearly parallel ranges at an average distance of sixty or seventy miles, of which the northernmost alone terminates near the Algerian frontier, its axis lying exactly in the line of the great shallow lakes or chotts that occupy a great part of the high plateau of southern Algeria, while the southern range, with some slight interruption, is continuous with the elevated zone that forms the northern limit of the Algerian Sahara. The details, however, as given in these recent maps are strangely discordant, especially in regard to the region lying E. and N.E. from the city of Morocco, and connecting the main range with the mountains of North Morocco.

It is not surprising that such discrepancies should exist, when it is known that the best maps have been compiled with no better materials than the reports of natives, and that none but a very small portion of the entire region has ever been traversed by civilized men. In regard to Gerhard Rohlfs, one of the most remarkable of recent African travellers, it must be remembered that he was forced to maintain a rigid disguise, to associate constantly with natives, and to suit his movements to theirs. He was unable to make more than scanty and occasional notes, and was altogether debarred from the use of instruments. It is not surprising that, under such conditions, his contributions to the topography of a region never before visited by European traveller tend more to excite than to satisfy curiosity.

During the spring of last year the Sultan of Morocco, at the request of the British Minister, Sir John Drummond Hay, granted permission to Dr. Hooker, the eminent Director of the Royal Gardens at Kew, to explore the portion of the Great Atlas subject to the Imperial authority; and although the main object of the party, consisting of Dr. Hooker, Mr. Maw, and myself, was to investigate the flora of the mountains, it was not unreasonable to expect that we should be able to make some considerable addition to existing geographical knowledge in regard to a region so little known.

Those who are best acquainted with Morocco will be least surprised to learn that in this respect the expedition has not borne abundant fruit. The obstacles which stood in the way were partly anticipated by us, but were in great measure insuperable.

The authority of the Sultan extends over but a small portion of the region included under the denomination Great Atlas; it is, in fact, limited to the northern declivity of the main chain, and only throughout the western part of this, for it extends to a distance at the utmost not more than 120 miles E. of the city of Morocco. The time at our disposal was too limited to enable us to explore even the limited field that was thrown open to us. The cares and responsibilities attaching to his official duties prevented Dr. Hooker from prolonging his stay in and near the mountains beyond about three weeks, and the private engagements of Mr. Maw compelled him to separate from us and to return to England at a still earlier date. But by far the most serious obstacle which we encountered arose from the persistent though covert opposition of all the persons holding local authority, aggravated and not seldom stimulated by the chief of our escort, whose charge, as we had been assured, was to remove all impediments from our path.

But for the difficulties incessantly placed in our way, we should undoubtedly have attained several of the higher peaks, and could not fail to have learnt a good deal respecting the disposition of the greater masses and the direction of the main valleys in the territory which we could not actually traverse.

In point of fact we were able to make but two considerable ascents. On the first occasion, when we ascended the Tagherot Pass in a storm of snow and hail that completely intercepted all distant view, the cold was so severe that we willingly turned our faces from the storm when only Mr. Maw, the foremost of the party, had actually set his foot upon the summit, about 12,000 feet above the sea-level. On the second occasion, after Mr. Maw had left us, we attained a conspicuous peak, called Djebel Tezah, about 11,500 feet in height, in a much lower part of the range than that previously visited. In addition to the very limited results of personal observation, we naturally availed ourselves of every promising opportunity for obtaining topographical information from natives. Much of the information obtained in this way appears to me utterly unreliable, especially when derived from persons holding local authority; but the particulars supplied by a very intelligent

Jew residing in Morocco, so far as they rest on personal knowledge, deserve more confidence.

The following are the chief points as to which I think myself entitled to express an opinion, premising that as to some of them I may place undue confidence in my own personal conclusions:—

1. The portion of the Atlas chain that is seen from the city of Morocco is considerably higher than has generally been supposed. The chief summits appear to be nearly of the same height, and the majority of these approach very nearly, if they do not occasionally surpass, the level of 14,000 feet. Westward of the district of Glaoui, S.W. of the city of Morocco, the range subsides gradually as it approaches the coast.

2. There is a certain amount of tolerable evidence tending to show that the interior part of the range extending from the upper valley of the Wed Tessaout to the frontier of Morocco contains peaks of higher elevation than any seen by us.

3. The existence of an anti-Atlas or range parallel to the main chain, and enclosing on the south side the great valley of the Sous, was established by Rohlfs, if not by previous travellers; but we are probably the first who have looked across the wide intervening space and scanned the outline of the anti-Atlas. The portion seen by us at a distance of from 50 to 60 miles is far less bold in form than the main range. The utmost height of that portion can scarcely exceed 10,000 feet.

4. The map compiled by Capt. Beaudouin, and published in Paris at the Dépôt Général de la Guerre in 1848, which is decidedly the best that has hitherto appeared, is defective in representing the main chain as arising abruptly from the low country, scarcely indicating considerable lateral valleys. At the same time it should be remarked that the projecting ridges which divide these lateral valleys appear to be lower, in comparison with the peaks of the main chain, than is usual in other great mountain-ranges.

5. There is a marked tendency to the formation of considerable valleys parallel to the main chain, and in such cases the remark made in the last paragraph does not apply. Some of the higher peaks, and amongst them that named Miltsin by the late Captain Washington, lie in ridges nearly parallel to the main chain.

6. It appears at least possible that the anti-Atlas, if we may so denominate the range forming the southern boundary of the Sous valley, is merely an example on a large scale of one of the parallel ridges just referred to, many examples of which are to be found in better known mountain-regions.

7. The existence of two parallel chains so continuous as those represented in Gerhard Rohlfs's map appears to be open to reasonable doubt. In the absence of direct evidence, it appears at least equally probable that the conformation of the main chain may be best represented by a series of ridges slightly inclined to the axis of elevation of the entire mass.

8. The remarkable valley of the Beninguald, laid down on Beaudouin's map as extending more than one hundred miles from S.E. to N.W. in a nearly direct line, must be pronounced imaginary or based on false information. The details given in Rohlfs's 'Reise durch Marokko,' however incomplete, are manifestly inconsistent with the general plan of the mountain-system laid down in that map.

On the Geographical Distribution of Forests in India. By Dr. Brandis.

In all countries the character of forest vegetation mainly depends on soil, climate, and the action of man. In India the greater or less degree of moisture is perhaps the most important element in this respect. Moisture and rainfall are not identical terms. In many parts of India and elsewhere dew and the aqueous vapour dissolved in the atmosphere, or the water derived from the overflow of rivers and from percolation, are sources of moisture as important for the maintenance of arborescent vegetation as the fall of rain and snow. It would greatly facilitate the labours of the forester and of the botanist, who inquire after the geographical distribution of forest-trees, if the amount of atmospheric moisture and the formation of dew during the seasons of the year in different parts of India had been sufficiently studied; but in the present state of our knowledge we must be satisfied with dividing

India into regions and zones according to the more or less heavy rainfall during the year. The arid region, with an annual rainfall of less than fifteen inches, occupies a large portion of the north-west corner of India, from the Salt range in the north to the mouths of the Indus in the south, and from the Suleiman range in the west to the Aravulli Hills in the east. It includes the southern portion of the Punjab, the province of Sindh, the States of Bhawulpoor, Khyrpoor, Bikanir, Jessulmir, and the greater part of Marwar. Throughout this vast region, which covers an area equal to that of the kingdom of Prussia, with a population of from twelve to fifteen millions, the rains are not only scanty but most uncertain. It is not a rare occurrence for several years to pass in succession without any showers, and then there is a heavy downpour, generally in winter, and occasionally in August or September. There are, however, no regular winter or summer rains. A scanty, thorny scrub on the hills and in the northern part in the plains also gives ample employment to the botanist, for it is here that the representatives of the Arabian and Persian flora mingle with the vegetation which is peculiar to India; but the work of the forester is mainly confined to the belts of low country along the Indus and its great branches. In Sindh, for instance, the area of forest land which is under the exclusive control of the State covers 350,000 acres, all situated on the fertile alluvial soil on both banks of the Indus, some of which is inundated annually by the summer floods of this large river, the remainder being moistened by percolation. In lower and middle Sindh a large portion of these forests consists of *Acacia arabica*, more or less pure, with a shade so dense that very little grass or herb grows under the trees. In northern Sindh extensive shrub-forests of tamarisk, with standards of *Acacia* and *Populus euphratica*, cover large tracts along the banks on both sides of the river. As the Indus changes its course from time to time, leaving dry last year's bed and breaking through at another place, forming a new channel, the fresh banks and islands which are thus thrown up are covered at once by a dense growth of self-sown seedlings of tamarisk, with a sprinkling here and there of the acacia and poplar; and in other places large tracts of old forests are carried away by the encroachments of the river. Outside these forests a little further inland, but still to a certain extent under the moistening influence of the river, are vast tracts of *Prosopis spicigera*, *Salvadora*, and *Capparis aphylla*, and further north, in the Punjab, where the rainfall is more regular and its annual amount approaches or exceeds ten inches, these dry woodlands, mainly composed of *Prosopis*, *Capparis*, and *Salvadora*, cover a vast extent of country between the rivers of that province. These woodlands are commonly known under the name of Rukhs, and they extend far into the second zone, which the author proposes calling the dry region of India, and in which the normal rainfall is between fifteen and thirty inches. There are two zones of dry country: one running on the north and east of the arid region in a belt from one hundred to two hundred and fifty miles wide, leaving the foot of the Himalaya range about Umballa, touching the Ganges at Futtehgurh, and including Agra, Jhansi, Ajmere, and Deesa. This he proposed calling the northern ry zone; its natural forest vegetation is scanty, but better than that of the arid region. In some of the States of Rajpootana there are extensive woodlands of *Acacia arabica*, *Prosopis*, and a species of *Anogeissus*, carefully preserved, to furnish cover for game, a regular supply of wood and grass, and, in times of drought, pasture for the cattle of the vicinity; and in some parts of the Aravulli Hills, where cultivation mainly depends on the water stored up in tanks, the value of preserving the scanty thorny scrub on the hills, in order to regulate the filling of the tanks from rain, is recognized by the larger landholders. Nor must we forget that we owe the maintenance of the forests in Sindh and of the rukhs in the Punjab to the action taken by the former rulers, and that during the first period after the occupation of the country the action of the British Government has not in all cases been favourable to the preservation of the forests and woodlands in the arid and dry regions of India. Great exertions have, however, been made of late years to make up in some measure for past neglect in this respect; and in the Punjab extensive plantations have been established since 1865, which now cover upwards of 12,000 acres, the main object in the formation of these new forests being to provide fuel for the consumption of the railways, and fuel and timber for the large towns in that province. There is a

second dry region in the peninsula of India, comprising part of the Deccan, the Maidan or open country of Mysore, and several districts of the Madras Presidency. There are exceptionally moist places within its limits, such as Bangalore, which, being situated 3000 feet above the sea, has somewhat more than thirty inches rain; but upon the whole, and excluding hills, which rise considerably above the table-land of South India, this belt, which stretches from Nassick in the north to Cape Comorin in the south, has a normal rainfall of less than thirty inches. This belt includes Poona, Bellary, and Kurnool in the north, and Madura and Tinnevelly in the south. Over a great part of it is found the sandal-wood (*Santalum album*), a small tree with fragrant heart wood, which comes up here and there in bushes and hedges, but does not grow gregariously and does not form pure forests. The moist tracts of country, with a normal rainfall exceeding seventy-five inches, are two. One is a narrow belt on the western coast, extending from Bombay in the north to Trevandrum in the south, and comprising the whole country below Ghat, and a narrow strip above Ghat, the latter varying in width at different places, but often only a few miles wide, although the fall on the crest of the Ghats is in places as heavy as 250 inches. The other moist region is much larger; it comprises the outer hills of the Himalaya range from Kangra to Assam, gradually increasing in width from a narrow belt twenty to thirty miles wide in the north-west Himalaya, and includes the whole of Eastern Bengal and Burma. The vegetation within these two tracts of moist country is exceedingly luxuriant and varied. The teak-forests (*Tectona grandis*) of Burma, Canara, the Wynaad and the Anamallays, the evergreen forests of Burma, Eastern Bengal and the western Ghats, and the extremely varied forest vegetation of the outer Himalayan ranges belong to this region. The greater part of Central and a large portion of Northern India belongs to what may be called the intermediate region, with a rainfall between thirty and seventy-five inches. The extensive sal-forests (*Shorea robusta*) of the sub-Himalayan tract and of Central India are found in the moister parts of this region. Where the rainfall exceeds forty inches, forest vegetation is fairly luxuriant; but the great drawback in this, as in most parts of India, is the circumstance that the rainfall is not equally distributed over the year, but limited to the rainy season, which varies in length from two to six months. The year thus, in most parts of India, divides itself into two seasons, the dry season and the rainy; and the dry season is generally the longer of the two. Dews and rare showers keep the grass and leaves in the forest fairly moist until January or February; after that time they dry up rapidly, and by March and April every thing is so dry that the smallest spark is sufficient to set it on fire. Hence the jungle-fires are an annually occurring institution in a great part of the country, and they do much to keep back forest vegetation. Successful attempts have, however, been made within the last six years to keep out fires in some of the more valuable forests, and the effect on the growth of the forest has been marvellous. In the Himalaya range moisture gradually decreases as we proceed inland, until a country is reached almost without rainfall, and with very little spontaneous arborescent vegetation. In the intermediate country, with a moderate supply of moisture, is the greater part of the Deodar forests (*Cedrus Deodara*), which furnish the north-west of India with timber. Here, as elsewhere, the influence of moisture on the rate of growth is remarkable. In the outer ranges, with a rainfall of sixty to eighty inches, the Deodar attains a diameter of two feet in from sixty to eighty years; further inland, in the dry region, at the same elevation, from 150 to 200 years are required to form the same quantity of wood.

On the Desiccation of South Africa. By Dr. J. C. Brown.

Remarks on the Deep-water Temperature of Lochs Lomond, Katrine, and Tay. By Alexander Buchan, *F.R.S.E., Secretary of the Scottish Meteorological Society.*

In two communications made by Sir Robert Christison to the Royal Society of Edinburgh in December and April last, on the deep-water temperature of Loch

Lomond, from observations made by him with a Miller-Casella thermometer, three important facts were stated:—

1. On the 12th of October, 1871, the temperature at the surface was 52°, from which it fell, on descending, till at 300 feet below the surface it stood at 42°; and this temperature of 42° was uniformly maintained at greater depths, or o 518 feet, the depth of the loch at the place of observation.

2. On the 18th of November following, the surface-temperature was 46°; at a depth of 250 feet 42°·25; at 270 feet and lower depths 42°.

3. On the 10th of April, 1872, the temperature at the surface was 43°, at 150 feet 42°·1, and from 200 to 591 feet 42°.

Hence it appears that there is a stratum of water of considerable thickness at the bottom of this loch of uniform temperature—that the upper surface of this stratum of deep water of uniform temperature was about 100 feet higher on the 10th of April than it was in the beginning of winter, or on the 18th of November—and that this deep-water temperature probably remains constantly at or very near 42°.

During this period the temperature was the average of the season on fifty-one days, the deficiency amounting to a mean of 3°·4; and above the average on ninety-four days, the excess amounting to a mean of 4°, the most markedly mild periods extending over sixty-nine days, viz. from the 11th of January to the 19th of March, during which the temperature was on an average 3°·9 above that of the season; and the temperature was, for the whole period of 145 days, 1°·4 above the average.

It may be concluded that in ordinary winters the stratum of water of uniform temperature will be thicker than Sir Robert Christison found it to be this year in the beginning of spring; in other words, that it will be nearer the surface than 170 feet.

The late Mr. James Jardine, C.E., made observations on the temperature of Lochs Tay, Katrine, and Lomond, in August and September 1812, and again in September 1814, and found the deep-water uniform temperature of the lochs to be 41°·9, 41°·7, and 41°·5.

These observations were made in the summer and early autumn, or when the temperature of the sea and of the lakes is about the annual maximum. Taken in connexion with Sir Robert Christison's observation, they warrant the conclusion that the deep-water temperature of Loch Lomond remains during the whole year either absolutely at, or very nearly at, the low figure of 42°.

Mr. Jardine's observations also show that this is not a peculiarity of Loch Lomond, but that it is also a characteristic of Lochs Katrine and Tay, and most probably of other deep waters.

The mean annual temperature of the air at Loch Lomond, from the mean at Balloch Castle, situated at the foot of the loch, calculated on the thirteen years' average ending 1869, is 48°, which is 6° higher than the uniform deep-water temperature of the loch. The deep-water temperature is, therefore, not determined by the mean annual temperature of air over this part of the earth's surface.

From Forbes's 'Climate of Edinburgh,' it is seen that the temperature there is under the annual mean from the 21st of October to the 26th of April. Assuming that this holds good for Balloch Castle, then the mean temperature of the air for these 188 days is 41°·4.

The close approximation of this temperature of 41°·4 to 42°, the deep-water temperature of the loch, is such as to suggest *that it is the mean temperature of the cold half of the year which determines the temperature of the lowest stratum of water at the bottom of deep lakes*, so long as the deep-water temperature does not fall below that of the maximum density of the water. As this principle, if established, would be of great importance in many questions of physical research, such as the deep-water temperature of the Mediterranean Sea, which Dr. Carpenter has very accurately ascertained, in its connexion with the larger question of general oceanic circulation, it well deserves further investigation.

Explorations in the Gold Region of the Limpopo. By E. Button.

The paper gave an account of journeys made by the author in 1869 across the Limpopo and in the neighbourhood of Lydenburg. After crossing the Limpopo in

the direction of the Bubyi river, a granitic country was entered, which continued to the furthest point reached, Matiba. The Bubyi has no running water in the dry season, but its banks are clothed with groves of a fan-leaved palm and a fine *Mimosa*, some of the latter trees forty feet high without a branch. The granitic formation of this region possesses very remarkable features; vast flats stretch away for a distance of sixty miles, studded with granite hills, each formed of a single mass of rock rising to a height of 600 to 1000 feet; the rock is denuded for miles, and the country a waterless desert. The natives build their huts under the shelter of large scales of granite on the sides of the hills and also on the bare rounded summits. No European could reach these places, but the inhabitants scale the hills with the facility of baboons. The author stated that there was very little hope of the Limpopo ever being rendered a navigable river, or the country settled by a European population. Lydenburg, further south, is situated in a fine agricultural district; and the country to the eastward, on the slopes of the Quathlamba, is very beautiful and fertile for a distance of 100 miles. In 1870 he discovered gold in a mountain-range south-west of Lydenburg.

On a Through Railway Route to India, viâ *Russia and the Oxus Valley. By* GRYF JAXA DE BYKOWSKI.

The author had traversed the route he recommended, travelling on horseback a distance of 2000 miles. He estimated the length of the line at 1900 miles, whereas the route from England, *viâ* the Euphrates valley, was 3185 miles. From the Volga to the Hindoo Koosh extended a plain, traversable even now by wheeled carriages. Crossing the Hindoo Koosh from Inderab to Planshir valley, there were only a few miles of mountain. It is true there were narrow gorges along the Cabul river, which would entail expensive works, but they were quite practicable.

On Dr. Livingstone's Recent Discoveries. By Lieut.-Colonel J. A. GRANT.

The author observed that it was much to be regretted that Dr. Livingstone's despatches and letters contained so few observations of latitude, longitude, and altitude, and that map-makers were consequently unable to lay down his vast discoveries with any degree of certainty. Dr. Livingstone had informed us that his great line of drainage had been traced by him from 12° S. lat. down to 4° S. lat., and that he believed the waters continued to flow beyond that until they joined the Bahr el Gazal, a western tributary of the Nile. But no such thing could happen. The Bahr el Gazal throughout its course was a system of marshes, stagnant waters overgrown with rushes and ambadj, and supplied very little water to the Nile. Moreover, Dr. Schweinfurth, a recent German traveller, of whose discoveries Livingstone, of course, could not be aware, had discovered the sources of the rivers of the Bahr el Gazal system in from 3° to 5° N. lat. From the facts recorded by Livingstone that pigs were kept by the natives of the Lualaba country, and that the gorilla was found there (both of which animals are unknown in the Nile Lake-region), the author concluded that the great traveller had underestimated the westing he had made in his longitude, and that he was really on the upper waters of the Congo, which flowed west into the Atlantic.

The Place of Geography, Political and Physical, in Education. By the REV. EDWARD HALE, *M.A.*

Every one is brought into contact with man and nature. The first aim of education should be to teach the duties we owe to man, our social duties, and to teach the advantages we may derive from a proper knowledge and application of the powers of nature. The social duties have been taught by means of philosophy and history. To learn these, the fathers of philosophy and history had to be studied in their own language. Hence arose the system of classical education, which at last degenerated into the mere teaching of Greek and Latin, or rather of Greek and Latin grammar, and this, too, not in a scientific manner.

But the study of nature has been practically ignored in education. Human philosophy has been taught, but not natural philosophy. Of late years there has been an attempted teaching of science in some schools, but it has been superficial. All school education should be thorough; but as boys and girls cannot learn much, what they are taught must be thoroughly taught, and must of necessity be rudimentary.

Education naturally divides itself into two branches, a human and natural philosophy—the one taught by literature and history, the other by mathematics and science. Those subjects, then, should be taught which are absolutely essential as introductory to both branches. These should be a language, ancient and modern, arithmetic, geometrical drawing, and geography. Political geography is the proper introduction to the study of history, as physical geography is to that of nature. Geography can be taught thoroughly, even when compulsorily taught, and can be made attractive both to pupil and teacher; whereas it is extremely difficult to teach chemistry or astronomy (for instance) compulsorily, and impossible to do more than teach them superficially. The method of teaching physical geography at Eton, not assumed to be the best method, is simply this: to teach by means of lectures, to use no text-book, to illustrate freely, to require constant reproduction of the lecture by the pupil in his own words, and to examine the pupils constantly by papers. One advantage of the method of employing no text-book is that it prevents "cram." Geography is, however, in itself a study which, provided the knowledge of the pupil is properly tested, admits of less "cramming" than any other study, partly from its great range, and partly from its admitting of so many problems being given.

Recent Changes of Level in Land and Sea. By H. H. HOWORTH.

This paper surveyed the evidences of all kinds of elevation and depression of land areas in all parts of the world, and the author believed they proved that a general elevation of the great land masses of the earth was in process, with some limited exceptions.

The Direct Highway to India considered. By Capt. FELIX JONES.

This paper advocated the construction of a railway to unite the Mediterranean at Alexandretta with Kowait on the Persian Gulf. The other proposed routes through Asia Minor, Northern Persia, or *viâ* Diarbekr and the left bank of the Tigris, were reviewed by the author, and shown to offer hopeless difficulties in the way of a line of railroad. Aleppo is the key to the entire system of railways in Turkey. A proposed line hence to Mosul would have the advantage of absorbing all the lines of traffic from the north and east; but in its continuation along the Tigris it would entail the bridging of the Euphrates twice and the Tigris once, besides being 300 miles longer than the route along the east bank of the Euphrates. The author spoke also of the more settled habits of the Arab population along this latter route, and of the manifest strategic and political value to England of this line and its two termini.

On the Relation of Forests to Hydrology. By G. LEMOINE.

The result at which the author had arrived in the investigations on which he had been officially engaged in France was, that the action of forests on the climate of a country must be considered as extremely doubtful. In the basin of the Seine it had been established that forests had no special influence on the supply of water in streams, as compared with similar areas of ground clothed with grass. The only absolutely certain action of forests was their influence on the protection of the soil, *i. e.* they prevented it being carried away by rains. In consequence of this action, they retarded, in mountainous countries, the flow of torrents; and this result had been well ascertained in the Department of the Hautes Alpes, where the replanting of woods had extinguished torrents already formed; but in most cases turfing alone had been found to produce an equal effect. These conclusions, in the opinion of the author, ought to be carefully limited to the countries in

which the subject had been investigated. They showed the extent of man's powers in influencing climate. He could so far modify the surface as to extinguish torrents; but the great general phenomena of the atmosphere, and the currents of air which determine the climate of a country, are beyond his reach.

Extracts from the Official Despatches of Dr. Livingstone.

The geographical information communicated in these despatches is contained chiefly in that to Lord Clarendon, dated the 1st of November, 1871. In this letter Dr. Livingstone states that he had ascertained that the watershed of the Nile was a broad upland between 10° and 12° S. lat., and lying from 4000 to 5000 feet above the sea-level. It is 700 miles in length from east and west, and from it flow innumerable streams, which further north unite to form two main lines of drainage—large "lacustrine" rivers, the exploration of one of which, called the central line, had occupied all the traveller's time and means down to the date of his despatch. The geographical results are stated to be chiefly as follow:—"The great river, Webb's Lualaba, in the centre of the Nile valley, makes a great bend to the west, soon after leaving Lake Moero, of at least 180 miles; then, turning to the north for some distance, it makes another large sweep west of about 120 miles, in the course of which about 30 miles of southing are made; it then draws round to north-east, receives the Lomame, or Loeki, a large river which flows through Lake Lincoln. After the union, a large lake is formed, with many inhabited islands in it; but this has still to be explored. It is the fourth large lake in the central line of drainage, and cannot be Lake Albert; for assuming Speke's longitude of Ujiji to be pretty correct, and my reckoning not enormously wrong, the great central lacustrine river is about five degrees west of Upper and Lower Tanganyika. The mean of many barometric and boiling-point observations made Upper Tanganyika 2880 feet high; . . . but I have more confidence in the barometers than in the boiling-points, and they make Tanganyika over 3000 feet, and the lower part of the Central Lualaba 1 inch lower, or about the altitude ascribed to Gondokoro [nearly 2000 feet]." The furthest point he reached to the north was stated to be lat. 4° S.

On the Panthays of Yunnan. By W. F. MAYERS.

On the Topography of Yeddo. By A. MOSSMAN.

On Polar Exploration. By Capt. SHERARD OSBORN, *C.B.*, *R.N.*

The author wished to draw the attention of the Association to Polar discovery, and to ask for sympathy and support in the efforts made by the Royal Geographical Society, in combination with other learned bodies, to bring about a renewal of Arctic discovery by British seamen and explorers. Since the return of Sir Leopold M'Clintock, in September 1859, from his memorable voyage in the 'Fox,' and foot journey round King William's Land, no British exploring-expedition had passed within the limits of the Arctic zone, and it appeared as if English geographical enterprise in the North had for a while become exhausted by the exertions made to rescue or learn the fate of Franklin's expedition. These exertions, which commenced in 1848 and ended in 1859, yielded a rich harvest of geographical exploration, as a comparison of the Admiralty charts would plainly show. From Baffin's Bay to Behring's Straits, through 90° of longitude and 8° of latitude, the whole northern shores of the American continent and the great archipelago to the north was not only explored, but almost every foot of coast-line was searched by ship, boat, or sledge parties. This great task was accomplished by much self-sacrifice, much labour, and considerable suffering, but without any casualties of a serious character. But though British Arctic enterprise rested from 1859, it was not so with other countries. The seamen and geographers of America (with that dogged

perseverance which formed one of their natural characteristics, never better illustrated than in the recent heroic journey of Mr. Stanley to the rescue of Livingstone) were not satisfied even by the news brought home by Rae and M'Clintock of the glorious fate of Franklin, with M'Clure's accomplishment by ship and sledge of a passage from the Pacific to the Atlantic Ocean, or with Dr. Kane's report of a passage, with much open water, extending northward through Smith's Sound; but they immediately sent forth, by private enterprise supplemented with Government aid, two fresh expeditions—one, under Captain Hall, to try on foot to reach Repulse Bay and the estuary of the Great Fish River, with the object of trying to save any documents left by the last survivors of Franklin's people; and the other to add, if possible, fresh geographical discoveries in the promising field of Smith's Sound laid open by the gallant Dr. Kane. Captain Hall for seven years lived the life of an Esquimaux and returned to tell us of a vast amount of relics of the crews of the 'Erebus' and 'Terror' being strewed about the shores and islets south of King William's Land, to bring home the bones of probably the latest survivor, Lieutenant le Vescomte, but only to confirm Sir Leopold M'Clintock's opinion, that by some sad fatality no written record beyond the one he picked up at Cape Victory existed of that lost expedition. Yet the ardour of Captain Hall was so little quenched by these long years of hardship that he again volunteered for Arctic labours, and was again now striving with a fresh-appointed expedition to secure to his country the honour of a polar exploration—Dr. Hay, who had been sent out on Kane's footsteps, having in the mean time returned, after carrying up the investigation of the shores of Grinnel Land, on the west side of Smith's Sound, to the 80th parallel of latitude, only 600 miles from the Pole, with much open water in sight. While our Transatlantic brethren had thus unflinchingly persevered in Arctic research other European nations had not been idle. Sweden had since 1860 sent scientific expedition after expedition to Spitzbergen, not only to explore that region, but also to test a theory of an open sea extending beyond it, by which the navigator could reach and explore the Polar area—that great unknown space, of more than a million square miles, lying around the pole and within the 80th parallel of latitude. Captain von Otler and Professor Nordenskiöld, after repeated gallant efforts, reported no probability of reaching it in that direction. Germany, for ten years, under the inspiration of Dr. Petermann, of Gotha, had been attempting unsuccessfully to reach these Polar waters by passing either between Spitzbergen and Nova Zembla, or between Spitzbergen and Greenland; and after encountering all the ordinary perils of the Arctic voyage, and exhibiting indomitable courage and perseverance, the German leader, Captain Karle Koldeway, returned to tell us in 1871 what Parry, Ross, and Franklin had told us half a century ago, that the outpour of ice between Greenland and Spitzbergen was too continuous and heavy for any navigator to push through, and that on the east of Spitzbergen an open passage to the Pole was a mere philosophical dream. Yet that latter course might still be a subject for geographical dispute had not two gallant officers of the Austrian Navy boldly essayed it from Tromso, in Norway, last year. The results of that enterprising little voyage had been so recently laid by Captain Osborn before the Royal Geographical Society that it was unnecessary to repeat it here; but one thing was certain, that as they went northward, and reached about the 79th parallel of latitude, to the east of Spitzbergen, they were fast approaching some unknown land of which glimpses had only previously been obtained. This land must block the passage in that direction, its existence accounting for the absence of drift Polar ice between Nova Zembla and the North Cape of Europe. These same Austrian explorers had again put forth with the intention of exploring the sea in a north-east direction from Nova Zembla along the shores of Siberia to Behring's Straits—a course likely to yield rich scientific and geographical results; and we could only wish them the "God-speed" they deserved at our hands. All these efforts by European nations, barring ourselves, during the last ten years, went to confirm the theory held now by nearly all our Arctic navigators, that the best, the safest, and most promising route towards the unknown Pole of our earth lay by way of Baffin's Bay and Smith's Sound; and by that route the President and Council of the Royal Geographical Society desired to see English navigators, associated with competent men of science, make a strenuous effort next year to

solve the mystery of whether around our Pole there lay unknown lands, an eternally frozen ocean, or an open sea; and he would earnestly call the attention of all lovers of science, or those to whom the honour of our country and the good of its naval profession were dear, to the "Memorandum on the Resumption of Polar Discovery," issued by the President, Sir Henry Rawlinson. The harvest which a properly appointed expedition would reap from a scientific point of view was incalculable, with our present knowledge of how well and safely to navigate and explore the Polar regions, as was proved by the success of all the English Arctic Expeditions from 1849 to 1859. The Government and the Admiralty had recently shown some desire, during a long period of peace, to promote, through naval expeditions, the cause of science; and he hailed, in the equipment of Her Majesty's ship 'Challenger,' under Captain Nares, associated with Professor Wyville Thomson, a return to that wise policy of our forefathers, which had added so much since the days of Cook, Banks, and Solander to the sum of human knowledge and the glory of our country; and he felt sure that an earnest representation by the associated scientific bodies of Great Britain, as represented by the British Association, would ensure the despatch of two small vessels, properly equipped, in 1873 to Smith's Sound, thence to return to us in a couple of years, bringing back a mass of information on all those questions of physical science which Dr. Hooker recently so eloquently pointed out could only be solved by a scientific exploration in the direction recommended by the Royal Geographical Society.

On the Physical Features of the Pamir and its Aryan Inhabitants. *By* R. B. Shaw.

The author gave as the results of his own observations and inquiries, and those of the late Mr. Hayward and recent Russian travellers, that the lofty Pamir Steppe was not a continuous open plateau, supported by a meridional range of mountains called the Bolor, but that it was composed of a series of parallel ridges running east and west, united by high plateaux studded with lakes, from which issued streams, some flowing eastward and others westward. The traditions of two great branches of the Aryan race pointed to this region as their birth-place. At the present time the beautiful valleys west of the Pamir are inhabited by a race totally different from the Tartar population both in appearance and in language, and claiming kindred with the Persian-speaking Tajiks of Bokhara. They are of fair complexion, often with light hair and hazel eyes, and their features are refined and handsome. Judging by the scanty vocabularies obtained by the author, their dialects, although indicating a close affinity with Persian, yet possess many roots which more nearly approach to Sanscrit forms, suggesting the idea of a link between these two Aryan modes of speech.

Discoveries at the Northern End of Lake Tanganyika. *By* H. M. Stanley.

Mr. Stanley prefaced the reading of his paper by an account of the origin of his project of searching for Dr. Livingstone, and of his journey to Ujiji and his meeting with the great traveller, an account similar to that which has already been made known to the public. He commenced his account of Tanganyika by stating that he was enabled to fill up the south-eastern shores of the lake (at present a blank on our maps) with rivers, marshes, and mountain-ranges, and people them with powerful tribes. From Unyanyembe he passed through Southern Wavinza, Ubba (three marches), the beautiful country of Ukaranga, and then crossed the Linche valley to the neighbourhood of Ujiji. At the time of his proposing to Dr. Livingstone a journey, in company, to the northern end of the lake, the Doctor was almost sure that the Albert Nyanza and Tanganyika communicated with each other. He had perceived, as he thought, a constant flow northward in the waters of Tanganyika; and all the Arabs and negroes persisted in declaring that the river Rusizi (at the northern end) ran *out* of the lake. As soon as Mr. Stanley mentioned to him the interest and importance attached to a settle-

ment of this question, he lost no time in preparing for the journey. Previously, as he stated, he had not regarded the subject as of any importance, the central line of drainage (*i. e.* the Lualaba) having absorbed all his time and means. Embarking in a boat, and travelling northwards from Ujiji, the two travellers hugged the coast of Ujiji and Urundi, looking sharply into every little inlet and creek for the outlet that was said to be somewhere. About fifteen to twenty miles were travelled per diem, past lofty mountains, rising sometimes 2000 or 3000 feet above the level of the lake, and camping ashore for the night. Several times they were in danger from the natives, and their men had to keep watch all night, lest they should be surprised while asleep. It took ten days to reach the head of the lake; on the opposite shore a mountain-range, ever bold and high, limited their western view and appeared impenetrable. The lake is of very great depth: Mr. Stanley sounded two miles from shore and found no bottom with 620 feet of line; and Dr. Livingstone further south, while crossing, found no bottom with 1800 feet of line. The mountains round the northern end fold around so close, with no avenue for the escape of waters, save the narrow valleys and ravines by which tributary streams reach the lake, that were the waters to rise 500 feet above their present level, the configuration of the lake would not be materially altered. The evening before they saw the Rusizi, a freedman of Zanzibar declared (in answer to their questions) that he had been on the river the day before, and that it ran *out* of the lake. This information caused the two travellers to deliberate on their further proceedings, should they find a channel leading into Albert Nyanza; and they decided they would in that case follow it and coast round its shores, in the hope of meeting with Sir Samuel Baker. The mouth of the river was at length found; it was in a little bay about a mile in width, and was masked by a dense brake of papyrus and *matete* cane. The entrance was not visible, and they followed some canoes which were disappearing mysteriously through gaps in the brake. Thus they found the central mouth, and all doubt as to whether it was an effluent or an influent soon vanished, for a strong brown flood met them, which tasked all their exertions to pull against. Higher up it widens into lagoons on either side. The alluvial plain through which the Rusizi flows into the lake is about twelve miles wide at the commencement, and fifteen miles in length, narrowing upwards to a point. The mountain-ranges on either side here approximate to within two miles, the eastern range passing the termination of the western. Further towards the north-west there was a perfect jumble of mountains. The chief Rubinga (near the Rusizi), who was a great traveller and readily discussed questions of geography with the two explorers, told them that the Rusizi rose in Lake Kivo, a sheet of water fifteen miles long by about eight broad, from which it escaped by a gap in the mountains. About twenty miles from its mouth the Rusizi is joined by the Luanda, or Ruanda, flowing from the north-west; and there were besides seventeen other tributary streams. Rubinga had been six days to the northward, but had not heard of a large body of water, such as Lake Albert Nyanza. Baker's lake, therefore, could not have the large extension southward which its discoverer had claimed for it. On their return journey to Ujiji, they coasted along the western shore of Tanganyika, visiting Uvira, where they were shown the sandy beach on which the canoes of Burton and Speke had rested. A little south of this rises the lofty peak of Sumburizi, 4500 feet above the lake-level.

Dr. Livingstone having sent home no map of his discoveries, or any material from which one could be constructed, beyond the descriptions in his despatches, Mr. Stanley, at the request of the President, pointed out, on a map of Africa, the position of the rivers and lakes, as near as he could recollect, from the map he had examined while in Dr. Livingstone's company.

On the Scope of Scientific Geography, illustrated by Remarks on the Climate of British India. By General R. Strachey, *F.R.S., F.R.G.S.*

The author contended that geography did not mean simply adventurous exploration, the result of which seldom went beyond an account of personal adventure combined with a bare itinerary; it was a science, and although much more com-

prehensive than other sciences in its scope, was to be cultivated, like them, by scientific method. It had for its foundation an exact description and delineation of the relative positions and characteristics of the various features of every region of the earth, which have then to be viewed in relation to the multitude of co-existing phenomena constituting the characters of the several regions, so that the laws of their mutual dependence may be finally deduced. This was usually called "Physical Geography;" but the author believed it more correctly to be the science of Geography. Each region had its special features of configuration, climate, and inhabitants, and the inquiry into the causes of these led us into a field which was almost conterminous with the entire circle of human knowledge. Such a field might seem too vast for individual powers, but it did not require especial devotion to the details of each branch of knowledge, but only the application of the leading results of each. Scientific Geography, in fact, formed the best possible view of the aggregate result of all the forces of Nature in a connected form. The author then gave a sketch of the system according to which, in his estimation, geographical observations ought to be treated in order to comply with the requirements of scientific method. He confessed that it might be difficult to realize this ideal in its completeness, and that the difficulty might be thought insuperable to a generation that has not received even an elementary education in physical science; but he had great hopes of the future. In applying his conception of geography to a description of the climate of India, he showed, by the aid of original diagram-maps, illustrative of the varying amount of rainfall, the temperature at different seasons, and the distribution of vegetation, how these phenomena could be explained as dependent on each other.

On the Question "Is the Asiatic Emigration to the West Indies likely to be a Permanent Fact in Modern Geography?" By Sir G. Young, *Bart., one of the late Royal Commissioners to British Guiana.*

After speaking of the condition of the few aborigines still to be found in the West Indies, and more particularly of those in British Guiana, the author described the state of the African portion of the population.

The negroes, notwithstanding all the waste of life and moral deterioration induced by slavery, had taken root in the soil, had been emancipated, and now formed the bulk of the population throughout the Antilles and in Guiana. The census returns showed that their rate of increase was very slow. In Guiana it was given at 9000 in ten years, upon a population standing in 1861 at 93,000, or a little under 1 per cent. per annum. He thought, however, that this might be looked upon as a temporary depression, and ascribed in part to the circumstances peculiar to a generation which had been nurtured in slavery or by emancipated slaves, and provided for by no masters. The men were vigorous, the women prolific; and an improvement in the domestic morals and in their treatment of their children, such as might reasonably be expected to accompany their growing material prosperity, would most probably restore their multiplying-power, which in the time of slavery stood higher than at present. It could not be doubted that the establishment of the African race in tropical America would continue to be a fact in modern geography; and what they had now to ask was, whether the new Asiatic immigration was of such dimensions and endued with such conditions of permanency as to render it capable of holding its own alongside the existing agriculturist negro population, and becoming in its turn a geographical fact. Economically speaking, the answer was of the utmost moment. The Africans, for the most part, contented with the sweets of liberty, and as yet new to the stress of those desires after luxury and comfort which impelled free races to hard continuous labour, had long ceased either to reside on the plantations or to supply them with labour sufficiently regular to ensure their profitable cultivation. From the ruin which, owing to this and other causes, fell upon the British West-Indian colonies twenty-five years ago, they had been resuscitated by the State-aided officially regulated Oriental immigration. Capital had been drawn to them afresh, fields had been reclaimed, public works undertaken, and a new era of prosperity appeared to have

been entered upon, owing to the introduction of the Coolies. Trinidad, which formerly stood low among her neighbours in point of enterprise and wealth, had doubled the area of cultivation and the amount of produce; the value of estates in Jamaica had in some cases already doubled since the Coolies, four years ago, began again to come after a six years' prohibition. It would be asked if it was possible that the results of the introduction of Africans during the time of the slave-trade could be matched by the immigration of Asiatic volunteers brought from a greater distance by government ships, under a system liable to be stopped at the first outcry of philanthropists, and so closely guarded that, as we learnt from the last Report of the Emigration Commissioners, the mortality during the Middle Passage had been reduced to below 20 in the 1000, a better rate than that obtained in many parts of England. Since 1843, however, 137,575 East Indians, 16,222 Chinese, altogether 153,797 of these immigrants, had arrived in the West Indies, Guiana and Trinidad between them taking nearly all the Chinese and 86 per cent. of the Indians. The average was 5000 every year during this period of thirty years; but for fourteen years of that time the immigration was very imperfectly developed, and occasionally even stopped. Since 1856 the average had been upwards of 7500 per annum, and during the last five years, in which no Chinese had come, the average arrival of Indians had been 7862; and there were no signs that there would be any falling off in the number so long as the laws of supply and demand were allowed to operate without interference. But this immigration was in its principle a temporary sojourn, not a permanent transference of home. A return passage was provided gratis for all East-Indian immigrants who had resided ten years in the colony, and served one five years' indenture; and the Chinese, although their return passage was not paid, were free to go at the end of ten years, and they were notoriously given to returning to their homes from other places. These facts, however, were of less importance than they might at first seem. At the present time less than 15,000 out of 137,000 Indians had claimed a return passage, while the number of them who had already spent ten years in the colony must amount by this time to 40,000 at least. The diminution in the number of applications for a return passage in the last year or two was traceable to the opening of Crown lands and the offer of allotments to coolies in exchange for their right of return. Thus, in Trinidad, 285 time-expired immigrants had already received allotments, and 96 others had purchased 910 acres at a stipulated price. The consequent saving to the colony already exceeded £4000. The lead of Trinidad was to be followed shortly by Guiana and Jamaica. It was worthy of remark that the planters, who originally opposed the scheme, fearing lest the coolies, like the negroes, should withdraw from plantation labour, now desired to have coolie villages in their neighbourhood, finding that the free labourers so settled were glad to work for them. It was not yet possible to answer the question of the increase of the Asiatic population by statistics. The mortality for the first ten years was frightful: the Commissioners lately in Guiana estimated that it reached 10 per cent. per annum. In 1851 one third of the whole number introduced within six years were already dead. The improved regulations of the passage, however, and the very great efforts of the planters and Colonial Governments, had brought down the mortality to a mere fraction of the former death-rate. In Guiana and Trinidad it fluctuated between 3 and 4 per cent. An important Government department was charged with the supervision of all matters in which the interests of the coolies were affected. A special labour law, on which great pains had been spent, was administered by stipendiary magistrates, in order to secure them work at fair wages. Medical aid was provided gratuitously, and no estate was without its hospital. After twenty years of this improved and still improving system, we found in Guiana that, of a population of 200,000, one fourth, or 49,000, were immigrants from Asia, while 6000 more were children of those immigrants, called Creole coolies in the colony. In Trinidad, of a population of 110,000, there were 24,500 immigrants and 5500 Creole coolies, making 30,000 in all. The female sex was as yet sadly deficient in numbers. The Colonial Office insisted on a *minimum* of 40 to every 100 males who were recruited, and would increase the proportion but for the extreme difficulty of making up the quota without resorting to women of a character likely to neutralize all the benefits intended by their introduction.

At the present time there were in Guiana women in the proportion of 42·21 to every 100 males, showing that the equalizing influence of the rising generation was beginning to tell. After instituting an interesting comparison of the relative working qualities of the Coolies and Negroes, he concluded by saying that he was inclined, though not without hesitation, to stake his credit as an observer upon the ultimate predominance there of the Negro, with a reservation, however, in favour of the Chinaman, if the Chinese immigration were resumed.

ECONOMIC SCIENCE AND STATISTICS.

Address by Prof. H. Fawcett, *M.P., President of the Section.*

The President opened the proceedings of this Section, and after a few introductory remarks, said:—Every one has been saying that we have been for some time past, and that we are at the present moment, enjoying unprecedented prosperity in this country. If the well-being of a nation could be solely estimated by the amount of wealth which is produced at home, and by the quantity of commodities which are imported from abroad, it might be concluded that England was rapidly arriving at a state of perfection, and that all her people were in process of securing an ample supply of the necessaries and comforts of life. Let us for a moment, then, ask whether such a result is likely to be realized by the prosperity which at present prevails. People are beginning to remark that prices are rapidly rising; and it seems to be discovered that the more prosperous the nation is said to be, the more certainly does an advance take place in the price of many of the first necessaries of life. If we are told that never before was so much wealth produced, that never before were the wages of so many classes of labourers so high, it may be with truth rejoined that never before were many articles of daily consumption so dear. There has been also a general rise in house-rent. It is at once obvious that unless the increased wealth which is produced is generally diffused throughout the nation, it will of course follow that in consequence of the rise of prices some people may find themselves not more prosperous, but worse off than they were before. There are a great many people whose incomes are either fixed in pecuniary amount or are regulated by customs which, if not unchangeable, require many years to be modified. Nothing is more common than, when a man dies, to leave his widow or his daughters a fixed income. Sometimes the income is derived from property which trustees are ordered to invest in some security such as the funds, in which the rate of interest is fixed; sometimes the income is a fixed pecuniary charge upon some property or business. Then, again, there is a numerous class, such as half-pay officers and superannuated clerks, whose incomes are also fixed. There are also others, such as clergymen, clerks, and others, in the receipt of salaries, whose incomes may ultimately advance if there is a general rise in prices; but after the rise has taken place, a considerable time will elapse before the advance is secured. It must also be borne in mind that although there may be a great increase in trade, yet the increase may not affect every business; and therefore in those branches of industry which remain unchanged, employers and employed may for a considerable time be unable to secure any increase in their remuneration at all commensurate with the augmentation in the cost of living. The operative and the miner have secured an advance of 20 or 30 or 40 per cent. in their wages; but it does not invariably follow that these advancing profits and this increase in wages should be at once accompanied by a corresponding advance in profits and wages in other industries and in other localities. If there is a great increase in the production of wealth, accompanied by a rise in the price of many of the necessaries of life, it does not follow that all are at once benefited; but, on the contrary, many temporarily suffer severely. When trade rapidly increases, it may happen, as it does at the present time, that there is a transfer of wealth, that some people are getting poorer as others are getting richer. In the congratulations which we indulge about national prosperity, let us not forget those

who not only do not at once participate in its advantages, but who actually suffer in consequence of it. But it may be asked, is the rise in prices, which is now so marked a feature in the economic condition of England, caused by the general activity of trade, or is it simply an accidental coincidence? If nothing occurs either to increase the supply of the precious metals, or if no change in the method of conducting business enables their use in many transactions to be dispensed with, it is a well-known principle of economic science that an increased production of wealth would cause, not a general rise, but a general decline in prices. It has, however, happened that, contemporaneously with the great development of trade which has occurred during the last twenty years, there has been an enormous increase in the production of the precious metals. It has been calculated that the total yield of gold since the gold discoveries in Australia and California, a little more than twenty years since, is about £500,000,000. This is supposed to be nearly equivalent to the entire quantity of gold existing in the world previously. There has also been a considerable augmentation in the production of silver. The effect which has thus been produced in cheapening the precious metals, or, in other words, in effecting a general rise in prices, has been greatly assisted by an extended use of credit, partly owing to greater facilities in banking. When the gold discoveries in Australia and California first became known, many predicted that there would be a great and almost immediate depreciation in the value of this metal. This prediction was not fulfilled. The gold discoveries occurred just at the time when there was a great development of trade, partly produced by the introduction of free trade, by the extended application of steam to industry, and by the development of the railway system. The additional supplies of gold were consequently for some time absorbed without any decline in its value. It can now, however, be scarcely doubted by any attentive observer that a considerable depreciation has taken place, and that this is indicated by a marked rise in prices, which is erroneously supposed to be due, not to this cause, but to a general activity in trade. The rise in prices which has taken place since 1850 is estimated by eminent authorities as not less than 40 or 50 per cent. This circumstance partly accounts for the fact that the augmentation which has taken place in the production of wealth has not produced a greater and more perceptible influence upon the general well-being of the country. If, for instance, we discover that during the past year 10 per cent. more wealth, estimated in money, was produced than in the previous year, and if during the same period there has been, owing to a depreciation in the value of the precious metals, a rise in prices of 5 per cent., it is at once obvious that one half of this supposed increase of wealth is not real, but simply nominal, because all commodities have advanced 5 per cent. It is not, of course, intended to be implied that there has not been a large and real increase in the production of wealth. It is, however, important not to omit the deduction to which allusion has just been made. But the reason which induced him to refer to the present general rise in prices was threefold. In the first place, he wished to point out the hardship and suffering which it will, at any rate for a time, cause to certain sections of the community; secondly, to show what precautions should be taken in order, as far as possible, to mitigate the influence of a similar cause in future; and, thirdly, to draw the practical conclusion that at the present time certain classes who are most unfavourably affected by the peculiar economic circumstances of the country are the very people upon whom the burden, both of imperial and local taxation, falls with peculiar severity and inequality. But it may probably be said, is not the present advance in prices temporary? Is there any possibility that it can continue and increase? In answer to such inquiries, it would be presumptuous to give a positive, dogmatic answer. There is probably no subject on which it is more hazardous to prophecy than on the future yield of the precious metals. Some people may argue that the yield of gold from Australia and California cannot be maintained. On the other hand, it may be urged with equal plausibility that the yield of gold may be greatly increased as labour in these countries becomes more plentiful, and as improved methods of mining are introduced. Without, however, attempting to decide between these two opposite opinions, we will adopt a middle course, and assume that about the present yield will be maintained. If this should be the case, it cannot be doubted that there will be a steady depreciation in the

value of the precious metals, and a corresponding advance in general prices; and it is obvious that if the rise in prices should continue, the loss which will be endured by those in receipt of fixed money-incomes will also continue. This being the case, we arrive at the second of the three points enumerated, and we have to seek a reply to the important practical question—What can be best done to mitigate the consequences resulting from such a loss? One or two practical conclusions may be ventured upon. In the first place, it is hazardous to tie down trustees or executors to invest money in some security in which the rate of interest is fixed. If the money is invested in any kind of property, or in shares which represent property, the money value of the property and of the shares will advance with the rise in prices. Workmen and others who can only make very small investments from time to time may, it is thought, have a great difficulty in finding such investments as those just recommended. It is, however, at once evident that if they purchase their dwelling-house by joining a building society, or if they invest their money in shares in some cooperative undertaking, they would avoid the risk of finding the value of their savings depreciated by a depreciation in the value of money; and this risk they would run if they set aside a weekly sum to purchase an annuity to commence some years hence. It may seem that some of these suggestions afford an argument against life insurance; but this is really not the case if a judicious choice of an office is made by those who insure. Many offices divide their profits, over a certain fixed percentage, among the policy-holders. If, therefore, the money is judiciously invested by the company, the money value of their property will increase with the rise in prices; consequently the amount to be distributed among the policy-holders will increase, and will afford a compensation for the diminution in the purchasing-power of the policy when it is paid. The third point to which he wished briefly to direct attention is the following:—In the present circumstances of the country, the possessors of small fixed incomes are those who participate least in the advantages resulting from activity of trade, and are also those who suffer most from the present rise in prices: and there is no class upon whom the burdens of local and imperial taxation probably fall with so much severity. As examples, take a widow, a clerk, a curate, or a half-pay officer, with an income of £200 a year. They are liable to the income-tax. The income-tax is not only made a permanent part of our fiscal system, but a precedent was set last year for defraying exceptional expenditure by means of the income-tax. No class probably has to spend so large a proportion of their income in house-rent; and it is, after all, upon the occupiers of houses that by far the most crushing effect of local taxation falls. But the most serious injustice that seems to be done them is associated with our poor-law system. In those branches of industry which are exceptionally prosperous enormous profits are realized, and a great advance in wages is secured. The additional wages are, to a great extent, spent and not saved. They are spent in the purchase of more beer, spirits, meat, butter, or the other articles of daily use. The price of some of these articles advances with this extra demand, and the possessors of fixed incomes suffer accordingly. No one would suppose that he (Prof. Fawcett) did not rejoice in seeing the workman receive a better remuneration for his labour, and have an opportunity of enjoying more leisure. But if his extra wages are all spent, and nothing is laid by, what may happen? Why, trade may become dull. Instead of there being the present demand for labour, tens of thousands of hands may have to be discharged. Nothing having been saved in prosperous days, how will they live without work? They will be able to claim the right to be maintained out of the rates, to no small extent contributed by the very class (the possessors of small fixed incomes) who do not now share in the present prosperity, and who find the cost of living increasing. This is the injustice to which he alluded. Not only does this injustice exist, but there is reason to fear that it may be increased. There is a general feeling at the present day that the burdens of local taxation press unfairly on certain classes. Admitting that some reform is needed, it must be borne in mind that unless we are careful we shall, in striving after greater equality, secure greater inequality. Some have gone so far as to suggest that there should be a national poor-rate, or, in other words, that the support of the poor should be made an imperial charge. But even if such an extreme proposal as a national poor-rate is not carried out, there is a demand, influentially

urged, that many local charges should, in part at least, be defrayed out of the Consolidated Fund. Without now attempting to decide whether such a proposal ought to be carried out, it should be remembered that two very serious dangers are associated with it, which ought certainly to be most carefully guarded against. In the first place, local authorities think that public money is no one's money, and consequently localities would vie with each other in getting as much out of the Consolidated Fund as possible. He had felt it his duty, on more than one occasion, to warn people against supposing, as they sometimes seem to do, that the Consolidated Fund is a great source of wealth, kept perennially supplied by the spontaneous bounty of nature. The Consolidated Fund represents taxation. If more money is obtained from the Consolidated Fund for local purposes, what new taxes is it proposed to levy? or which of the existing taxes is it proposed to increase? This question will be answered by the electors, the majority of whom are not the payers of income-tax. They have been encouraged by what has been done in the past to throw the whole extra charge on the income-tax; and the income-tax would fall with the greatest inequality upon the possessors of small fixed incomes, who are placed in the most unfavourable position by the general economic circumstances of the country. Allusion has already been made to a remarkable rise of prices which is going on at the present time. So far as the increasing dearness of commodities is due to such natural causes as the demands of a larger population, it would be neither possible nor desirable to attempt to control it. Indications, however, are not wanting that the cost of producing many commodities may be artificially augmented by the incessant demands which are constantly being put forward for mischievous legislative interference with industry. If we had time to examine the various measures that were introduced into Parliament last year, and the various measures with which we are threatened next Session, it would not be difficult to show that, unless we are very careful, industry will be hampered by State interference much in the same way as a machine would be if sand were thrown among its wheels. Such lessening of industrial efficiency would increase the cost of producing commodities, and the great mass of the people would have greater difficulty than they have now in obtaining either a sufficiency of the necessaries or an adequate supply of the comforts of life.

On the Pollution of Rivers. *By* Major-General Sir JAMES E. ALEXANDER, *F.R.S.E.*

Statistics regarding the Attendance and Education of Girls in the Elementary Schools of Manchester.* *By* LYDIA E. BECKER.

In a recent speech at Willis's Rooms, the Bishop of London is reported to have said, "In the lower classes the girls were as well provided for in the matter of education as the boys." This statement appears to be one of those comfortable delusions by which men, who do not care to discuss what are called women's rights, blind themselves to the actual condition of the feminine portion of the community. The education and remuneration of the teachers of girls prescribed by the code of the Education department are inferior to those of the teachers of boys, and consequently an inferior quality of instruction is the natural result. Besides these disadvantages, which operate uniformly over the land, there are others which may vary according to the character of the population and of the district. There is a general belief that education is less desirable for girls than for boys. More schools are provided for boys than for girls. Girls are more frequently kept at home to attend to nursing or household labour than boys. The operation of these causes is strikingly shown in the experience of the School Board of Manchester. The number of children to be provided with school accommodation in the district of Manchester is (according to the calculation adopted by the Education department, namely one sixth of the population) 58,557, consisting of

* Printed *in extenso* in the 'Englishman's Review,' October 1872.

16,396 boys, 16,932 girls, 25,179 infants. The whole accommodation provided by all classes of elementary schools within the city was, when the Board began its work, for 48,548 children, and it was thus divided:—for boys, 18,795; for girls, 14,603; infants, 15,150. Thus, while there is a total deficiency of 10,000 in the number of school-seats compared to the number of children, there is an actual excess of 2399 for boys over the total number of boys in Manchester, and a deficiency of 2379 in the accommodation for girls.

Turning from quantity to quality of education, we find a still greater disparity between the sexes. The following statistics regarding the subjects studied were compiled by the clerk of the Manchester School Board from returns furnished by the teachers:—

Subject of Lesson.	Number of children in each subject receiving instruction therein.			
	Boys.	Girls.	Infants.	Total.
Geography	4295	2083	..	6378
History	1979	739	88	2806
Grammar	3517	1710	..	5227
Needlework	..	8160	1074	9234
Object Lessons	159	120	1070	1349
Singing by Note	767	180	269	1216
Drawing	1260	218	..	1478
Bookkeeping	92	20	..	112
Composition	16	5	..	21
Geometry and Mensuration	72	..	..	72
Algebra	270	..	..	270
Euclid	124	..	..	124
Animal Physiology	70	..	..	70
Natural Philosophy	265	140	..	405
Political and Social Economy	210	..	..	210
French	10	..	..	10

The result is to show that in these elementary schools the boys, after mastering the mechanical and preliminary subjects of reading and writing, are allowed an introduction into matters which have a tendency to enlarge their mental view. The girls, instead of partaking in these advantages, are occupied with the practice of needlework. The School Board of Manchester gives comparative discouragement to the education of girls by its by-law, which fixes the fee to be paid for girls at only three fourths that of boys. The following Table shows the amount of school fees paid during one year for boys and girls respectively:—

Quarter ending	Boys.			Girls.			Infants.			Mixed.			Total.		
	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.
Sept. 1, 1871	253	17	6	128	15	1	216	19	6	124	5	5	723	17	6
Dec. 1, 1871	255	1	8	141	5	4	217	16	5	98	13	11	712	17	4
March 1, 1872	226	17	8	132	4	6	211	5	8	84	13	10	655	1	8
May 31, 1872	242	9	4	126	4	10	269	9	6	122	11	2	760	14	10
	978	6	2	528	9	9	915	11	1	430	4	4	2852	11	4

The number of school orders granted, and of attendances made, show an equally unsatisfactory result as regards girls. The figures refer to the poorest classes of the people, as the orders are only granted in cases where the parents from poverty are unable to pay the school fees:—

Nine months ending May 31, 1872.	Boys.	Girls.	Infants.	Mixed.
Orders granted	5,892	4,775	9,208	3,320
Orders used	5,126	4,025	8,053	2,910
Per cent. of orders not used	13·00	15·70	12·54	12·34
Attendances possible	485,316	381,054	773,722	278,053
Attendances made	366,757	255,900	562,442	201,807
Per cent. of possible attend. made	75·57	67·15	72·69	72·57

The writer suggested (1) that no girl be exempted from full-time school attendance unless it be shown that her labour is absolutely necessary for the support of the family; (2) that in every case where a girl is exempted from attendance at morning school, it should be a condition that she be exempted from needlework at afternoon school, and the whole of her school time devoted to intellectual exercises.

The importance of providing additional facilities for the Instruction of School-Board Pupils in the Higher Branches of Knowledge. By C. G. Bunting.

The Elementary Education Act, spite of its deficiencies, will yet be regarded as one of the greatest benefits ever conferred by Parliament upon the country.

Having laid the foundation of a sound elementary education and made provision for its attainment, it is time to consider what steps shall be taken to provide for those scholars who shall make the best use of the advantages now placed within their reach the means of obtaining further instruction in the subjects now designated "extra" by the Education department.

The power given to School Boards to exempt from compulsory attendance such children as may pass examination in a specified standard, though attended with some advantages, is a great drawback to progress in the advanced subjects. It does not seem right to reward a scholar for proficiency in obtaining knowledge by helping him to withdraw from the opportunity of adding to it. Such reward ought rather to be facilities for additional instruction.

In each School-Board district, Government scholarships should be open to all students in advanced subjects. The examination upon which the attainment of a scholarship would depend should be conducted in such a manner as to ensure its possession being regarded as a high honour. It ought to be supplemented by some useful prize, which should be presented to the successful candidate at a gathering of members of school boards, school managers, and parents of the scholar. Such scholarship should secure to its possessor the advantage of a sound university education, for which it may be necessary to establish some half dozen colleges in different parts of the kingdom. The scholarship should secure the right to three years' residence in one of these colleges (provided its holder passes a yearly examination) and instruction in the higher branches of science, art, and literature from some of the most proficient teachers the Government could secure. Each student who shall pass a special examination at the end of his three years' course shall be entitled to a fellowship worth from £80 to £100 annually, to be held till he obtains employment at a salary equal in worth to such fellowship. Its possession ought always to be considered a qualification for the civil service. As this fellowship would be regarded as the "blue ribbon" of school-board educational contests, the author suggested that it might be presented at the annual meetings of the British Association by the President for the time being.

On International Decimal Coinage. By Herbert Burgess.

The writer assumes that the establishment of an international coinage is simply a question of time, also that any such coinage will be decimal. He then points

out that there are now in use two systems of decimal coinage—the French, based on the franc, and the American, based on the dollar; five dollars being equal to twenty shillings and ten pence, and twenty-five francs to nineteen shillings and seven pence, one standard of value being thus slightly above, and the other slightly below the English. He gives the preference to the former of these two systems, but considers that one better than either may be formed from our English coinage, by doubling our pound for the largest unit and dividing by 10, 100, and 1000, making four coins of account of the respective values of 40*s.* and 4*s.* and nearly 5*d.* and ½*d.* These four coins he has named *arch* (from the Greek ἀρχή, and as used in monarch &c.), *dor* (French d'or, golden), *silver penny*, and *an* (old English one), but lays no stress on these names, which he does not consider an essential point.

These coins (except the smallest) he would, for convenience of currency, divide into halves and quarters, making altogether four gold coins=40*s.*, 20*s.*, 10*s.*, 4*s.*, four silver coins=2*s.*, 1*s.*, 5*d.*, 2½*d.*, and one bronze coin=½*d.*, thus using the chief part of our present issue without alteration, the only coins that could not be used being the half-crown, the sixpence, and the fourpenny and threepenny pieces; the bronze penny might be allowed to go gradually out of circulation, no new ones being coined. That despised and troublesome coin, the farthing, would be abolished altogether, the experience of both France and America showing that no coin so small is necessary; the smallest coin in circulation would agree with the smallest denomination of account, as it now does in America but not in France, while the largest would also agree with the largest, as it now does not in either France or America.

The actual values of the coins of different countries would be made to agree by being raised or lowered as each case requires; but as the English values hold the medium place, and her pound sterling is a value universally well understood and appreciated, and she herself is the acknowledged centre of the commercial world, her standard seems to be the most natural and advantageous that can be chosen.

The French mint might raise the values of its coins to accord with ours, by ceasing to charge a seignorage for coining, but giving to each coin a weight of its full value in bullion as is now done in England: this, if universally adopted, must greatly facilitate transactions in bullion, as its value would be exactly expressed by its weight in coin.

Our English accounts would be converted into the new denominations by dividing the pounds by two, the shillings by four, and the pence by five, adding one *an* for every shilling reduced to pence for the purpose of division.

The French accounts would require simply dividing by five; the American only that the decimal point should be shifted one figure further back; for example:—

	£	*s.*	*d.*		francs.	centimes.		dols.	cents.
English	43	17	8½	French	1097	10	American....	219	42
New accounts	21·942			New accounts	21·942		New accounts	21·942	

In cases where smaller sums are required to be represented, as in marked quotations &c., the decimal point might be used; thus, 8¾*d.*=17·5 ans, 8⅜*d.*=16·75 ans, $8\frac{7}{20}$*d.*=16·7 ans. This is one particular in which this system would have an advantage over any based on the French franc and centime, which latter is a coin much too small to be used, yet not small enough for quotations; as, for instance, in the cotton market, where $\frac{1}{16}$ths are often quoted. Another point is that the largest denomination would make a very handsome and convenient gold coin (about the size of our florin), on the other side neither 10 francs nor 100 francs would make a good coin for the largest in circulation, one being too small and the other too large.

Again, the Russian accounts would be brought into accord with the 4*s.* unit more easily than with the ten-franc unit, the rouble, =3*s.* 1*d.*, being (near) three quarters of the former, while it is three eighths of the latter, which latter proportion is one not readily understood nor easily calculated by the mass of the people. This remark applies also to the German coinage based on the thaler, =2*s.* 11*d.* The Austrian, based on the florin, would also be with no great difficulty converted

into that here proposed, two florins being equal (nearly) to the second unit, the *dor*, and twenty to the largest, the *arch*.

The system here advocated will be seen to be much better suited for large accounts than is that of the Americans (which is thought by them destined to replace all others), yet so near an approach to it as to make it very easy for them to convert theirs into it: it would also be a much easier change for France than the adoption of her system would be for us.

Many countries have now in use coins nearly agreeing with some here proposed; indeed there is a remarkable series of coins very near in value to the proposed dor, 4s. This approximation, though of no use for international purposes, which would require exact agreement, would avoid any great disturbance in the internal commerce of each country—the new coins agreeing so nearly with the old that one would be commonly accepted as equivalent to the other, as our bronze pennies are taken as of the same value as the copper coins which they have replaced, although intrinsically worth less.

On Polygamy as affecting Population. By Hyde Clarke, *F.S.S.*

By the investigation of new facts obtained from the lives of the Turkish Sultans, and the kings and princes of Europe, it was proved that polygamous individuals do not produce a larger permanent progeny than the monogamous, and that population is not increased by the union of one man with a large number of women, but limited by the law of fecundity in man. Although the total number of births, the offspring of one man, may be large, and cases were cited of above one hundred, the progeny surviving in his lifetime or perpetuated afterwards in no case exceeds that of a man married to one woman at a time or successively. It was further suggested that an element in the perpetuation of polygamous issue is intermarriage with the offspring of the monogamous.

Suggestions for improving and extending our National Accounts; being a continuation of Mr. Fellows's Paper read at the Edinburgh Meeting, "On a proposed Doomsday Book, &c." By Frank P. Fellows, *F.S.S.*

This paper commenced by assuming that the previous suggestions of the author "On a proposed Doomsday Book, giving the Value of Governmental Property as a basis for a sound system of Accounts," would be endorsed by the present Meeting, and that it was not therefore necessary again to discuss them. This the author assumed because the Statistical and Economic Section of the British Association had at Edinburgh, after the reading of that paper, unanimously passed the following resolution, which, as it also stated the groundwork of that paper, was given here, as forming the text or commencement of the paper about to be read. The resolution was as follows:—

"That this meeting having heard Mr. Frank P. Fellows's paper on a proposed Doomsday Book, giving the value of national Government property as a basis of a sound system of national finance and accounts, desires to urge upon the Government the great importance of the subject, and would strongly recommend that measures be taken to inquire into and report upon the question. The Meeting desires further to express its opinion that each Government department should have, like railway or other public companies, a capital and a current account, without which it deems it impracticable to have a reliable system of finance and accounts, and would suggest that a scheme of accounts should be introduced by which a unity may be established between the Parliamentary finance and departmental expense or other accounts, in order that the various sums voted by the House of Commons may be traced to their ultimate appropriation in statistical results, and so that greater control may be obtained over the national expenditure, and that the President (Lord Neaves) be requested to communicate this resolution to the Government authorities."

This was moved by Sir John Bowring, F.R.S., and was seconded by Mr. H. W. Freeland, late M.P. for Chichester, and was carried unanimously.

After briefly recapitulating the main points of the paper read at the Edinburgh Meeting last year, viz. "On a proposed Doomsday Book, giving the Value of Governmental Property as the basis for a sound system of National Accounts," the paper proceeded to develop still further the author's views as to the manner in which Government departmental accounts should be prepared for the information of Parliament. In the paper read at Edinburgh, it was suggested by the author that, in addition to the main proposal of the paper, a Doomsday Book of National (as distinguished from Governmental) property might also be compiled after the manner of the old Doomsday Book of William the Conqueror; and this minor suggestion had been advocated by the 'Spectator' and other influential papers and also by Earl Derby, and there seemed some probability of its being carried into effect.

The great object, however, of the main proposal (*i.e.* of having a Doomsday Book giving the value of Government property) was to obtain thereby the basis of a good system of Parliamentary and Departmental accounts, by which expenditure for the current purposes of the year might be distinguished from expenditure which really went to increase the capital of the Government—which, for instance, went to increase its land, buildings, stores, &c.

It was urged that there could be no efficient check on expenditure or the results of expenditure by Parliament if disbursements for capital and for current purposes were not clearly distinguished, as departments might obtain from the House £10,000,000 and expend either £11,000,000 or only 9,000,000, simply because the extra million might be obtained by reducing the capital (*i.e.* plant, buildings, stores, &c.), or by not maintaining them to their usual value, and thus £11,000,000 be spent for current purposes; or £1,000,000 extra might be expended for increasing the capital (in plant, buildings, stores, &c.) of the department, and thus only £9,000,000 be spent for the current purposes of the year in question.

The author pointed out in detail how the various departmental accounts should be compiled, so as to give the heads of Departments and Parliament greater control, so that they might see not merely that the money was disbursed to the proper recipients, and that there was no malappropriation, but that they have value for the money expended—that is, Expense or Statistical accounts of some kind (and the author pointed out how this could be done) should be compiled to show the results of expenditure.

To object to the expense of obtaining this information appeared like objecting to have reins to drive the coach on account of the expense of such reins, and electing to let the horse and coach take their own course.

In illustration, the author pointed out that between the years 1863 and 1866 he had discovered, and Mr. Seely had mentioned in the House of Commons, about thirty ships which had been repaired during that time by the Admiralty, the cost of such repairs being about equal to the sum for which similar new ships could have been bought. It was a rough rule with shipbuilders that an old repaired ship was worth about half as much as a similar new ship, so that there had been a loss on these ships of some hundreds of thousands of pounds. An account of them would be found in the Appendix to the Report of Mr. Seely's Committee of the House of Commons of 1868, "On Admiralty Monies and Accounts."

This was now obviated by the system of Expense accounts and by the way they are utilized at the Admiralty, so that such cases could not well occur again.

In the author's opinion three things were necessary for a perfect check:—

1st, audit of cash; 2nd, audit of stores, as to quantity, for stores are money's value, and an audit of them is as necessary as an audit of cash; 3rd, Expense or Statistical accounts showing the results of expenditure in ships built, repaired, articles produced, or in other results. Without this we may have perfect audit of cash; and of stores we may see that the stores said to have been used to a ship have been so used, and yet they may have been used very improperly, or may have been employed uselessly, as in the cases of excessive cost of repairs of ships given in this paper, or expensive stores or labour may be used where inexpensive stores or labour would suffice. In fact gold may be used instead of iron, and hundreds of thousands of pounds be wasted in this way; and the heads of Departments and the House of Commons, seeing that they have a perfect check or audit of cash and

stores, may be perfectly satisfied, and be thus lulled into a false security. The author urged the necessity of such accounts being initiated and supervised by an independent authority outside the Departments, and gave suggestions in detail as to how this might be done.

On a Proposal for supplying Pure Water to Villages and Country Parishes in Central and Eastern Divisions of England. By Professor HULL, *F.R.S.*

On the National Union for Improving the Education of Women. By Miss SHIRREFF.

This Association dates only from November last year, when a public meeting was held to inaugurate it upon a plan previously sketched out by Mrs. William Grey, and to name a central committee for its management. The long list of members now shown by the circulars of the Union, recognition of its work by important public bodies, numerous local committees formed and provincial societies affiliated, mark the progress made during the few months of its existence. Of the work proposed it is only possible to say here that the scheme aims at correcting the deep and widespread defects in women's education, by bringing into extensive cooperation all existing efforts at reform, by using all endeavours through as many channels as possible to kindle a deeper interest on the subject, and to combat the indifference of parents and of the public.

That indifference rests mainly on the absence in the case of girls of those direct motives of interest which prompt the instruction of boys. Those motives might be seen to exist by all who consider the waste of national resources caused by the ignorance of women—half the intellectual force of the nation allowed to do no work for the community. In sanitary questions, in questions of expenditure, of luxury, of the earliest training of children, the loss caused by the ignorance of women is beyond calculation. A very interesting paper in the 'Revue des deux Mondes' pointed out the loss to the trade and commerce of France caused by the incapacity of women to do any of the higher work; and this incapacity the writer traced not to want of technical training, but to want of cultivated intelligence. Fathers might feel that, even as a question of domestic economy, they would gain by enabling daughters to earn salaries, and their own business might gain in points beyond money value if their daughters were taught to take a share in it.

The evil and the loss are immense, and they are justly charged upon men, because the wealth and power of the country and of each family are in their hands, and they have refused to women the means of purchasing the education they require. The National Union, in its labour for reform, will earnestly press this view. But, besides striving to influence public opinion, it enters zealously into all practical schemes for improving the education and supplementing the very scanty means that exist of obtaining proper instruction for girls, such as classes for ladies and for working women, attendance at examinations, &c. It also gives earnest attention to the work of obtaining a fair share for girls of the rich endowments which in many cases were originally intended to benefit them, but which have been monopolized for the use of boys.

But its most important work is the spread of good schools. They are wanted everywhere, and for the whole portion of society which separates those whose children attend the elementary schools from the wealthy and aristocratic.

Some good schools exist, more probably than are known: Miss Beale has raised the Ladies' College at Cheltenham to the rank of a great educational institution, and Miss Buss offers us in London the very model we desire to follow; but a few such schools only point the contrast and make the general want more apparent. The Union has determined on trying the instrumentality of a limited liability company, by means of which, not one school but a whole system of schools shall in succession be founded. This plan is now commencing operations. The Girls' Public Day-school Company is about to establish its first school in the S.W. district of London. The fees in such schools cannot be so low as in endowed

schools, for they must be such as will afford not only the highest payment that can secure first-rate teaching, but a moderate dividend on the capital, without which all hope of future schools would be at an end. But too much is often said about low fees; they may be so low as to be only a disguised form of charity, and the middle classes of England can pay and ought to pay for the education of their own daughters. When the difficulty is too great, the elementary schools offer the rudiments of knowledge, soundly and thoroughly taught, at so small a cost that the saving made by placing some children there would probably suffice to pay for sending the more promising of the family to higher and more expensive schools; and there will have been no sacrifice of real education, such as would follow from sending girls to one of the genteel seminaries, where bad French, bad music, and worse arithmetic are taught at the cost of all that strengthens character and disciplines the understanding. One great difficulty has been how to secure to a commercial company its true educational character; this has been met, as far as possible, by inserting in the articles of association some points that are considered of the most fundamental importance. Two only can be mentioned here:—1st. The Company will found none but public day-schools, opened to all classes and denominations; 2ndly. Every school founded by the Company will have a class of student teachers. The training of teachers is one of the most important subjects and one of the most neglected in England. It is curious to find that it is still a question supposed to admit of discussion; to us it seems that as well might a doctor practice without knowing medicine or a lawyer without studying law, as a teacher pretend to educate without studying the principles of human nature and the methods of education. As every good hospital is a school for medicine, so should every good school be a training institution for teachers.

Women have every inducement to follow this training. Tuition is the only liberal profession opened to them, and their own ignorance has so depressed their condition that they occupy a different level altogether from that occupied by male teachers. And, again, all women ought to study education, because by natural position the large majority of them are necessarily educators, while all more or less come in contact with children. The conditions of their life require that all should be fit to be trusted in the nursery as in the sick room, and therefore that all should study the conditions of health and the principles of education.

The National Union, in order to carry so many important objects, can use influence only and appeal to the friends of education in all parts of the country to give aid in spreading right views and in combating prejudice, working steadily and methodically till some symptoms of better days shall appear when England may no longer think the education of her daughters a matter of no national importance.

On the Economic and Nutritive Value of the three principal Preserved Foods, viz. Preserved Milk, Preserved Meat, and Liebig's Extract of Meat. By Dr. Edward Smith, *F.R.S.*

MECHANICAL SCIENCE.

Address by Frederick J. Bramwell, *C.E., President of the Section.*

The practice of commencing the business of a Section by an Address from its President has been so generally followed for many years past, that it may be looked upon as more than a practice, and as being in effect a rule of the British Association.

Under these circumstances I feel that were I to consult my own inclination, and were to refrain from taking up your time by delivering an address, I should be guilty of a disrespect towards you, and should be setting a bad example to the Presidents who will succeed me, and who, under the excuse of my departure from

an established custom, might abstain from reading addresses which would be really instructive to their hearers. This being so I have an excuse for that which would otherwise savour of impertinence. I say of impertinence, because it is undoubted that many of the Members present, and, in fact, probably all the Members present, are so well instructed in the matters pertaining to our Section, that I cannot put forward any thing which will be new to them. It is this which gives the appearance of impertinence to an address; but the custom which renders an address obligatory takes away from that appearance. And there is another cause which also redeems it from that appearance, and that is, that although the hearers of the address will not hear any thing which they did not know before, it may bring things to their minds which they did know, but which were lying, as it were, in abeyance; and thus they may be forcibly reminded of subjects which they had somewhat neglected.

It is on these two grounds of custom and of exciting attention to that which may be for the moment forgotten, that I alone venture to take up time by addressing gentlemen, many of whom are my seniors, if not in life, at least in experience of our profession.

The question now arises, What, among the vast range of matters which fall within the scope of the Mechanical Section of the British Association, shall I select for the subject of my address?

I am aware that some of our former Presidents, on taking the Chair, have dealt generally with the progress and state of engineering knowledge,—they have, in fact, generalized. But in order to render an address of this kind useful, the writer of it must be a man of a grasp of intellect sufficiently large to really take in the leading subjects of Mechanical Science, and to deal with them in a comprehensive although a compendious manner. Such a power as this is possessed but by few, by the few who are men of deep thought and large experience, and who have the faculty not only of appreciating that which is taking place round about them, but the further faculty of arranging, classifying, and putting into methodical order the various facts which their minds have embraced, and then of communicating the very essence of this mental arrangement to those whom they address.

Such powers and faculties unhappily are not mine: I will not therefore attempt a task in which I must signally and utterly fail were I to essay it, and I must content myself with confining my observations to some one subject of interest.

The point I now have to determine is, what shall my one subject be? on what shall I address you?

I have thought over many subjects connected with Mechanical Science, but I cannot discover any thing more practically important than "Coal." Very few matters are of greater real interest at all times to the nation at large, and very few are more prominently before the minds of the public at the present time; and certainly no subject can be more appropriate for a mechanical engineer, if for no other reason than this, that the steam-engine is still the very crowning glory of mechanical engineering, and that coal is the staff of life and, so to speak, the breath of the nostrils of the steam-engine.

I am aware it may be said that the subject of coal is a hackneyed one: no doubt it is. We have had Coal Commissions; we have had letters in scientific and non-scientific publications, indulging in all sorts of speculations as to how long the known deposits of coal could last, and what were the probabilities of discovering new sources of supply; but I do not propose to trouble you at all upon the geological feature of the matter; and with respect to the statistical aspect, I will merely state in reference to it that the raisings of coal, which in 1855 were only 64 millions of tons in Great Britain, rose to 80 millions in 1860, and to 108 millions in 1869; and I will also advert to the fact that the price of all kinds of coal has in the colliery districts risen, speaking in round numbers, about 100 per cent. within the last twelve months, and is still rising.

This increase of consumption and this rise in price are startling facts, and force us seriously to reflect upon the use and also upon the abuse of coal. These reflections will make us remember that whatever the known store may be, and whatever new discoveries of other beds may be made, the supply after all is but a finite quantity—that, unlike the fuel wood, which grows year by year to replace the annual con-

sumption, the fuel coal is given to us once and for all—that we are therefore dealing with a store that knows no renewal—that if we waste it, the sin of that waste will be visited upon our children—and that it becomes us to look upon coal as a most precious, valuable, and limited deposit, of which we are the stewards and guardians, justified, no doubt, in using all that we require for legitimate purposes, but most criminal in respect of all that we waste, whether that waste arise from wilful indifference or from careless ignorance, an ignorance culpable as the indifference itself.

This being so, let us see how we do deal with coal in those cases where coal must be used, how we might deal with it in such cases, and how we might in certain instances substitute other sources of power for the coal which we now consume.

And let us first of all consider this question of finding sources other than coal for our motive power.

Before the steam-engine was so extensively used as it now is, the wind, the force of streams, and the force of the tide were all employed to give motive power.

With respect to the power of the wind, it is to be feared it is too irregular to enable any manufacturer to rely upon it in competition with the steam-engine.

With respect to the power of our streams, the altered condition of the soil, due to increased drainage and cultivation, has so materially interfered with the regularity of their flow, that their efficiency as sources of constant power is seriously diminished, while competition with them by steam has become much greater than it was when the water-mills themselves were better off. This state of things, however, might be cured, and, in fact, has been cured in certain districts by the union of a large number of mill-proprietors to form storage-reservoirs, from which the water can be delivered with regularity, so as to give a uniform supply to the mills.

But the third source of water-power, the tide-mill, which at one time was used to a considerable extent, is now almost wholly discontinued. The causes of this discontinuance are sufficiently obvious.

The tide-mill, as formerly constructed, could work for only a limited period in each ebb; and, to obtain the full effect, it had to utilize both the night and the day tides. But while tide-mills laboured under these disadvantages, they possessed the great merit that their power, such as it was, was one that could be depended on, and one which, although it fluctuated, fluctuated regularly and within known and definite limits.

I would suggest that in those cases where there are large manufacturing districts within a few miles of the sea, and where there is a large rise and fall of the tide, coupled, in the outset at all events, with natural indentations of the coast, which might be comparatively readily dammed up for the storage of the water, there such storage should be made, that the water should be put to work turbines of the best kind (turbines which will work with very nearly the same percentage of the total power given out by the water at any particular moment, whether they are immersed or whether they are not), that these turbines should be employed in pumping water at a high pressure into Armstrong accumulators, and that pipes should be laid on from those accumulators to the neighbouring manufacturing town, and should there deliver their power to the consumers, requiring it to be used by them in water-pressure engines.

Suppose a beginning were made with the city of Bristol, which is no doubt a very favourable instance for the application of this suggestion.

Here the rise and fall of the tide might safely be taken at 24 feet. Half a square mile of water enclosed would, after the most lavish deductions for loss, yield in Bristol at least 5000 horse-power, probably sufficient to replace the whole of the power of the stationary engines now at work in Bristol.

I will not detain you by further dilating upon this subject: but it does appear to me, looking at the opportunity which good turbines give of utilizing the power residing in water under constantly varying conditions of head, looking at the fact that by Sir William Armstrong's arrangements this power may be transferred to an extremely small quantity of water under high pressure, and that therefore such water may be transmitted for many miles through pipes at low velocities, even although those pipes be of no great size,—looking at these facts, I say, I cannot

help thinking that there is here open to the talent of the mechanical engineer a new field of enterprise, and one which, if successful, would tend to economize the fuel we so much value, and to leave more of it for consumption in metallurgical operations and in other operations requiring heat.

Before quitting the subject of finding sources of power other than steam, the Section will perhaps permit me to remind them of what has been done in the town of Schaffhausen by a public-spirited inhabitant in the way of utilizing the water-power of the Rhine, and of laying it on, so to speak, to every man's door. This has been accomplished by erecting turbines, which are worked by the river, and deliver their power to endless wire ropes carried over pulleys placed alongside the Rhine, the rope extending nearly from one end of the town to the other. This rope gives off power at the end of each street abutting on the river-bank, and that power is conveyed along those streets by a shaft in a channel under the paving. Each manufacturer can make his own communication with these principal shafts, and thus obtain the power he may require. I believe that no more is charged than is just sufficient to pay for the current repairs and for depreciation.

I will now consider the question how coal is wasted in its use; but before doing so I will say a few words upon the loss that occurs in the coal-mine itself. Happily this loss has for some years past been greatly reduced. More economic systems of working have prevailed, plans of dealing with small coal by washing away its impurities, so as to render it fit for coking, have been largely adopted, and thus a great deal of that coal which a few years since would have remained buried in the mine, as not justifying the expense of raising it to the surface and of paying royalty upon it, is now brought to light and is utilized. Nevertheless we know that at ordinary prices of coal it is to the advantage of the colliery proprietor, in many instances, to leave a considerable percentage of the seams that are worked, rather than to endeavour to lesson that percentage by the use of a more expensive system of artificial support for the roof; and, further, that it also pays him to leave altogether unworked very thin seams of coal.

Hereafter, when coal becomes scarce, there can be no question but what the inhabitants of these islands would be glad to make use of the now despised unworked seams, and also to recover the buried coal of the worked seams; but such seams and such savings, although they can be worked and made at present, when the mines are open, if not at profit, yet with little loss, will then only be capable of being reached by a reopening and pumping out of abandoned mines, a process so expensive that great indeed must be the need of our successors if they are compelled to resort to it. It is, however, difficult to see what remedy can be provided for such a state of things as this. I am far from suggesting that Government should interfere, and should say, "If you work your coal at all, you shall work the whole of it, and you shall not merely select those portions which will make it the most profitable speculation for you at the present day, but which will cause a large percentage to remain ungotten." I am far from suggesting this, as I hold Government interference to be in most instances such a mischievous thing that it is, as a rule, far better to put up with a certain amount of shortcoming and negligence than to call in as a remedy a power which is generally more injurious than that which has to be remedied. But in the absence of any such interference, it follows, from the ordinary principles which regulate commercial transactions, that a considerable percentage of coal in many districts will never be brought to the surface, because at the present time it does not pay to bring it. Thus in the very outset we are wasting fuel. But the prevention of this source of waste is a question quite as much for the mining engineer and the political economist as for the mechanical engineer. I have, however, mentioned it before this Section because the mechanical engineer may contribute to such prevention by devising new modes of extracting coal in places where hand-labour would press too heavily upon the men engaged in the work, and where, therefore, their labour would be too costly.

I now come to the question of the way in which waste occurs in the use of the coals that are brought to the surface.

This use may be divided into two great branches, the domestic and the manufacturing. I will consider first the domestic use.

This is a highly important branch of the subject. It is believed that out of the

total of 98 or 99 millions of tons of coal which in 1869 were retained for home use, $18\frac{1}{2}$ millions of tons, about one fifth of that quantity, were consumed for domestic purposes (about 10 millions being exported).

We all of us know so intimately the way in which coals are burnt for domestic purposes that I fear it will seem an idle waste of time to describe it. Nevertheless I really must occupy a few moments in so doing. We put a grate immediately below and within a chimney, and as this chimney is formed of brickwork, by no possibility can more than the most minute amount of heat be communicated from the chimney to the room. On this grate we make an open fire: fire cannot burn without air, and we provide no means whatever for the air to come into the fire; this is a provision that not one architect or builder in a thousand dreams of making. The consequence is that the unhappy fire has, as it were, to struggle for existence. In a well-built house especially it has to struggle; for the doors and windows shut tightly. The result is that the fire is always smoking, or is on the verge of smoking. We breathe the noxious gases and we spoil our furniture and pictures; nevertheless, happily for us, the fire does succeed in getting supplies of air which, even although insufficient for the wants of the chimney draught, do renew the air of the room. If to satisfy the demands of the chimney and to stop its smoking a window is left a little open or a door is set ajar, we complain of draughts, and we complain of the unhomely look caused by sitting in a room with an open door; so that there we are, with an asphixiated fire, our smoky rooms, and our draughty rooms. Moreover, the fire being immediately below the chimney, the main part of the conducted heat inevitably goes up it and is wasted, leaving the room to be warmed principally, if not entirely, by the radiated heat; and we do and suffer all this in order that we may see the fire and be able to poke it. For myself I must confess that if there was no cure for the evils I have described other than the close stoves of the Continent, with the invisible fire and with the want of circulation of air in the room, I would rather put up with the whole of our present domestic discomforts, and even with the loss of heat, than resort to the stove as a remedy. But there are modes by which freedom from smoke, freedom from draught, efficient ventilation, and utilization of the heat may all be combined with the presence of the visible pokable fire. Some members of this Association may recollect the paper that was read before it at the Norwich Meeting in 1868 by Captain Douglas Galton, in which he so clearly described his admirably simple invention of fire-grate. This consisted in putting a flue to the upper part of the fire-grate, which flue passed through a brick chamber formed in the ordinary chimney, which chamber was supplied with air from the exterior of the room by a proper channel, and then the air, after being heated in contact with the flue in the chamber, escaped into the room by openings near the ceiling, so that the room was supplied with a copious volume of warm fresh air, which did away with all tendency to draughts from the doors and windows, and, moreover, furnished an ample supply for the purposes of ventilation and combustion. These fire-places, I regret to say, have been but little used in England, from a cause I shall have to advert to hereafter—a cause which, as I believe, stands in the way of the adoption of improvement generally. The merits of these fire-places were at once acknowledged by the French, who made the most careful and scientific investigation of their working; and they found that with such fire-places three times the effect was obtained from a given weight of coal that could be got with those of the ordinary construction. No doubt there are many other plans by which the same end as that attained by Captain Galton may be arrived at; and yet we go on year after year building new houses, making no improvement, exposing ourselves to all the annoyances, and, worst of all, wasting the precious fuel. Assume that we were to set ourselves vigorously to work to cure this state of things, can it be doubted that in ten years' time we might halve the consumption per household, and do that not only without inflicting any discomfort or depriving the householder of any gratification, but with an absolute addition to warmth and an increase of cleanliness, a benefit to health and a saving of expense? Moreover it must be remembered that with the imperfect combustion of domestic fires, large volumes of smoke are poured into the air. We know how much freer from smoke town atmosphere is in summer time than it is in winter time, and this simply on account of the smaller quantity of coal

that is being burnt. Suppose that we could reduce the total consumption both in summer and in winter by 50 per cent., what an enormous boon that would be even in the one matter of a pure atmosphere!

The other way in which we use coal is for purposes of manufacture; and this, again, may be divided into two branches at least—namely, the coal that is employed for obtaining power and the coal that is employed in metallurgical and other operations not immediately connected with the production of power. To treat of these latter cases first, they are far too numerous to be dealt with in detail, and a few of the principal therefore only must be considered. Take the subject of coke-making. How much coal is heated in clamps and in kilns to be converted into coke, and in how few instances is any use made of the whole of the heat residing in the gaseous parts of the coal which are driven off. This heat frequently amounts to 30 per cent. of the whole of that which is in the coal.

We come next to the smelting of iron. Take the preliminary process of calcining the ore. In those cases where the ore is "black band," the ore so common in Scotland, the calcining is done by the combustion of the carbonaceous matter mixed with the ore. Far more than the quantity of fuel requisite for the calcination is associated with this ore; but the whole of it is burnt off, and no effort whatever is made to utilize the surplus heat. Then, with regard to the blast-furnaces for smelting iron. Here still, almost universally in Scotland, that large seat of the iron manufacture, and to a considerable extent in England, the waste gases are suffered to issue from the furnace-top, illuminating the country for miles round, and bearing testimony to the indifference of the owner of the furnaces to a waste of our store of fuel. Upwards of 60 years ago, viz. in 1811, the utilization of these gases was suggested in France; but not much was done for 30 years. About 1810, however, their use became not infrequent in that country, and their manufacturers and chemists taught us that the gas thus recklessly wasted might be collected and utilized, and made to replace the fuel expended in heating the hot blast-stoves and in raising steam for the blowing-engines. But, for the cause which has been and will be alluded to, the adoption of this plan was very slow indeed in England. It has now been in use, however, for many years in our best conducted works; but, as a proof of the slowness of its introduction, the furnaces of Scotland, as I have already said, are even to this day almost universally worked upon the wickedly wasteful principle of allowing these gases to burn idly away.

Take, again, the melting of steel in crucibles, where the heat issues from the furnace of necessity hotter than the heat of the melted steel (for were it not so it would cool it); and of this issuing heat, as a rule, no use whatever is made.

Take, again, the heating-furnace and puddling-furnace of our ironworks; very commonly from these heat at a greater temperature than that of welding iron escapes up the chimneys disregarded, as though it had cost nothing for its generation.

In many works, it is true, a portion of this heat is utilized for generating steam; but far more steam can be obtained than is required, even with the most unnecessary and lavish consumption of it, and thus in great ironworks boilers in which the steam is generated by the waste heat of the furnaces may be seen constantly blowing off large volumes of steam at the valves; and many furnaces are in use to which no boilers are applied, for the simple reason that they would be absolutely superfluous. This waste of heat in steel-melting and in furnaces for iron and for other metallurgical operations is by no means necessary, although it might be urged that it is; and it might be said that if a furnace is to heat a body to 3000 degrees, you must of necessity allow the heat to escape at that temperature, or rather at something above it, or else in lieu of heating the body you will be cooling it, and that you can no more trap escaping heat than you can trap a sunbeam. But one of my predecessors in this Chair, Mr. Siemens, has, as we know, shown us that you can trap the heat, and that you can so lay hold of it and store it up that the gases as they pass into the chimney from the furnace in which there is, say, even melting steel shall be lowered in their temperature down to that which will not char a piece of wood; and he has shown us how this stored up heat may be communicated to the separate streams of incoming air and gas of his gas-furnaces, so that they shall enter the furnace at a high temperature, that temperature to be increased by their union and combustion in the furnace. So beautifully can this trapping of

heat be carried out, and so successfully can the heat be retained by very trifling attention on the part of the workmen to the apparatus, that Mr. Ramsbottom, the late Locomotive Superintendent of the London and North-Western Railway, knew he should not be applying too delicate a test when he inserted the ends of pieces of wood through openings into the outgoing flues of the steel-heating furnaces at Crewe. These pieces of wood were padlocked in their places, were taken out periodically, and if they were found to be burnt it was known that the man in charge of the furnace had been negligent in his duty of saving fuel and had mis-used the Siemens apparatus. But although this invention has been before the public for very many years, and although it has had the approval of Faraday and of every other distinguished scientific man who has investigated the question, and, I am glad to say, the approval of the leading minds among the users of furnaces, nevertheless, for the general reason I shall have to allude to, the progress of this invention has been by no means commensurate with its importance; and it is not too much to say that manufacturers would rather waste cheap coal than embark capital in new furnaces, and, more than all, be at the trouble of instructing and of watching over their workmen.

Next, let us consider how we are dealing with coal when we use it for obtaining motive power in our steam-engines.

Steam-engines may be divided into the four great heads of marine, locomotive, portable, and fixed. Including within the term steam-engine the boiler as well as the engine, waste may arise in a steam-engine in two ways, either in one of them or in both combined. It may arise from an imperfect utilization of fuel in the production of steam (that is, a waste due to the boiler and to the firing), or it may arise in an improper use by the engine of the steam provided for it by the boiler. There can be no question but that the boiler waste is, as a rule, very large indeed.

A pound of fair coal is theoretically capable of evaporating from the boiling-point 13 lbs. of water. I do not believe that I shall overstate the case when I say that on an average not more than from one third to one half of this quantity is obtained from the whole of the boilers in use.

This poor result arises from a variety of causes:—1st, bad firing, which means bad combustion; 2nd, insufficient surface to absorb the heat; 3rd, an unclean condition of that surface either from internal or external deposit, or both; 4th, a faulty proportioning of the parts of the boiler to each other and to the work to be done, which cause heated water to be carried over with the steam—a cause of deficiency of evaporation, which, however, so far from being as a rule detected, goes to swell the apparent duty of the boiler.

Bad firing may result in the fire being too thick, or too thin or irregular. If too thick, the carbonic acid that is generated by the combustion of the lower part of the fuel with which the air first comes in contact is changed in its passage through the upper part of the fuel into carbonic oxide, by absorbing from the fuel a second equivalent of carbon. If this gas, carbonic oxide, does not meet with free atmospheric air, and meet with it at a suitable temperature in the upper part of the furnace, it must remain unconsumed, and will pass through the flues or tubes of the boiler and make its escape into the air, carrying with it the valuable unconsumed carbon of the coal in a gaseous form. It is commonly said that smoke is unconsumed fuel. This is true: but it is not commonly recollected that there may be invisible smoke arising (even from a coke-fire) which shall contain the highly combustible ingredient carbonic-oxide gas. When it is remembered that every pound of coal burnt into carbonic acid is capable of evaporating, as has already been said, about 13 lbs. of water from 212°, while a pound of coal converted only into carbonic oxide is capable of evaporating but 4 lbs., it will be seen how necessary it is that no mismanagement of the fire should cause a portion of the fuel thus to escape unburnt up the chimney.

Another defect in the management of a fire (an opposite defect, as it were) by which coal may be wasted is the admission of too much air; and this arises when the fire is too thin in relation to the chimney-draft, or when (a more common evil) it is thin in places, owing to the negligence of the firemen in keeping it properly levelled.

The way in which waste arises from these causes is, that unnecessary air is introduced into the fire at a temperature of, say, 60°, and that this air has to be heated, and then (even if the heat be abstracted from it, as far as practicable by the boiler) it will escape up the chimney at a temperature of from 200° to 300° in excess of that which it had; and the whole of this excess represents wasted coal. Thus, on the one hand, it is of importance that there should be a proper amount of air to secure the perfect conversion of the carbon into carbonic acid; and, on the other hand, it is most desirable that this amount should not be exceeded, involving the necessity of uselessly heating air not wanted for combustion. Such a happily balanced state of things it is almost impossible to secure by hand-firing, almost impossible, but not absolutely impossible, though only attained at competitive trials, and when these trials are conducted by highly skilled men.

In such trials of portable engines before the judges of the Royal Agricultural Society of England, the firemen will put coals upon the fire as frequently as forty-five times in an hour, the quantity put on at each time being, as may be supposed, little more than a spoonful.

Writers on the management of the steam-engine usually advise that the fire-doors should be opened as little as possible, and that the firing should take place about every quarter of an hour.

Under ordinary circumstances they may be right; but when it is desired, regardless of the amount of manual labour, to obtain every particle of useful effect out of the fuel, it is then found to be remunerative to open the door, not four times an hour, but more than forty times an hour, taking care, however, that it is only opened for the fraction of a second. It is by this frequent feeding of a small quantity of coal, distributed over the fire, that the competitors are enabled to insure a uniform condition of that fire to receive the action of the air. They know precisely the amount of draught they have got, and by experience they also know what thickness of fire will exactly balance, as it were, the air that comes through, so that the combustion may be perfect, and yet there may be no free air. But in ordinary hand-firing, done at intervals of a quarter of an hour, it is obvious that the thickness of the fire at the end of such an interval must be very different from that which it was at the beginning of it, and thus if that thickness be right in relation to the draught at one time it must be wrong at another. At one time, immediately after firing, there may be a distillation of the coal, producing black smoke and carbonic oxide; this will go on till the fire burns thin and burns into holes, when there will be a passage of free air. I do not wish to be understood that I am advocating the attendance of skilled firemen to fire forty-five times in an hour. Coal must be far dearer than it now is to make it pay so to occupy a man, or rather watches of men; for no one man could submit to such continuous labour for more than from four to five hours. But my observations tend to call your attention to the subject of mechanical firing. I believe that the high evaporative duties that have been obtained by the use of liquid fuel, duties approaching very closely indeed to the theoretical power of that fuel, are largely due to the fact that the air and liquid can be injected in definite and regular proportions, insuring perfect combustion.

Again, in the use of powdered fuel by Mr. Crampton, where the powder is blown into the furnace by the very air which is there to enter into combustion with it, very high evaporative results have been reached even under the disadvantageous circumstances attendant upon early experiments; and this also I believe to be due to the power of accurately adjusting the quantity of air to the fuel to be burnt.

The same power of adjustment may be obtained in those instances where the fuel is previously converted into gas, as practised by Mr. Siemens; and nearly similar control can be got with ordinary fuel by reverting to some of those systems of mechanical fire-feeding which were in use from twenty-five to thirty years ago, but which have been to a great extent abandoned in consequence of the more general adoption of internal fires and high-pressure boilers. The fires of such boilers are in furnaces of small diameters, which do not admit of the introduction of the apparatus, for which room was readily found below the bottoms of the waggon-shaped boilers formerly used for low-pressure steam. Other modes of fire-feeding, however, have been devised, and have come, to a certain extent, into use. It is

not the object of this address to enter into the details of such matters as these. I will therefore content myself by saying I am perfectly certain there is hardly any subject more worthy the attention of the engineer than the replacing the stoker by some mechanical arrangement which shall afford absolute uniformity of firing, and therefore absolute uniformity of the conditions of the fire; and this is a subject not only worthy of attention on account of the saving of coal, but also on the ground of putting an end to a most laborious, exhausting, and, it is to be feared, unhealthy occupation—viz. that of the steamboat fireman, more particularly when he is working in a hot climate. If perfect combustion were obtained in the fire, I do not think there would be much difficulty in properly utilizing by the boiler the heat evolved. All that is necessary to attain this end is to give a sufficient amount of surface to absorb the heat and to transmit it to the water, always bearing in mind that, above all, the form of the boiler should be a safe one, that there should be proper water-space within it and an adequate water-surface from which the steam could escape, that it might do so with tranquillity, and so as not to give rise to the spray technically known as "priming," and that all parts of the boiler should be accessible for cleaning.

I am aware there is a temptation, on the score of saving expense and of saving room, to make the boiler of small size in relation to the amount of coals burnt under it and to the quantity of steam required from it; but this is a most extravagant economy,—it is a saving in the outset, but it is a perpetual source of loss in the working. Temperatures as high as 800 and even 1000 degrees of heat have been known to exist among the products of combustion escaping from the boiler. Now when it is recollected that every 100 degrees of heat in the outgoing products of combustion represents $2\frac{1}{2}$ per cent. of the whole heating-power of the coal, even if only the minimum amount of air to ensure perfect combustion is admitted, it will be seen how necessary it is that there should be sufficient surface in the boiler to absorb the heat of the gases, and to bring them down to a few degrees above the temperature of the water in the boiler itself. I have mentioned the temptation to use boilers of inadequate size on the score of expense and on the score of room. It is this latter reason, no doubt, which induces shipowners to endeavour to diminish the size of their boilers as far as practicable, because they argue that the space occupied by the boilers and machinery is all waste room, as it cannot be filled either with coals or with cargo. With short-voyage steamers, voyages of a few hours only, this argument may be a valid one; but for the long-voyage vessels to India and elsewhere, where fuel has to be carried for from twenty to thirty days' steaming, and where on the homeward voyage the ships have to be supplied with coal that has been brought from England by sailing-vessel at a large cost for freight, the true space deducted from the cargo and passenger-carrying power of the steamship is clearly not that occupied by the engines and boilers alone, but that occupied by the engines, the boiler, and the coal for those boilers. Even supposing that if, after enlarging the boilers to diminish the consumption, the space to be given up to the engine, boilers, and coal were still the same, in consequence of the increase in the size of the boilers being equivalent to the coal-space saved, manifestly it would be to the advantage of the shipowner that that space should be occupied by the boilers rather than by the coals.

The expense of the boilers is a first outlay, and has not to be repeated for years until the boilers wear out; but the expense of coal is an outlay that has to be made at every voyage, and therefore it is a short-sighted policy to restrict the amount of absorbing surface in a boiler on the plea that a boiler with full surface takes up a greater space in the ship, if by doing away with such restriction a saving can be effected in the fuel.

The beneficial results which are attained by the greater size of boiler in relation to the coal burnt and to the horse-power required can be shown not only by calculation, but by example. In Her Majesty's ship 'Briton,' fitted with extremely economic compound engines of Mr. E. A. Cowper's design, close upon two pounds per horse-power per hour were burnt when the ship was making thirteen knots; but on being worked at ten knots the consumption fell to $1\frac{3}{10}$ lb. of coal for the lesser horse-power then used.

I will now say a few words upon the engines.

The locomotive engine has for many years past being doing very fair duty. This has arisen, I believe, first, from the fact that since the introduction of coal the furnaces have been to a considerable extent gas-furnaces with a free admission of air through open fire-doors to the surface of the fuel.

Second, from the fact that the boilers have large absorbing surfaces. From these causes as much as 9 or 10 lbs. of cold water are commonly evaporated per lb. of coal, while the engines working with high steam and considerable expansion make a good use of that steam.

In Marine Engineering there has within the last ten years been an enormous improvement. The old-fashioned engine working at 20 lbs. steam, and with injection-condensers, is being abandoned for engines generally on the compound-cylinder principle, working at 60 and 70 lbs. steam highly expansive, and fitted with surface-condensers. The result is a reduction of the consumption of fuel in the same vessels on the same voyages, and performed in the same time, of from 40 to 50 per cent. of that which was previously burnt; but I believe that a large field for improvement in marine engines still remains, especially in the firing and in the size of the boiler.

Among the best instances of what can be done in the way of economy may be mentioned the rapidly increasing class of portable agricultural engines.

These engines, like the locomotive, are, from their migratory condition, incapable of being fitted with condensers, and thus must be worked as non-condensing engines, exhausting their waste steam into the air—a most serious disadvantage. Nevertheless such great advances have been made by the unremitting attention of the extremely skilful mechanical engineers who construct these engines, that at the late Cardiff Meeting of the Royal Agricultural Society of England one of the engines (the prize engine, that of Messrs. Clayton and Shuttleworth) ran for five hours and one minute with 14 lbs. of coal per horse-power, being therefore a little under $2\frac{8}{10}$ lbs. of coal per horse-power per hour; and this was the horse-power of the dynamometer break, and not the mere indicated horse-power by which marine engines and other engines are ordinarily judged. The indicated horse-power is, of course, in excess of that developed upon the break, as the indicated power includes all the engine-friction and break-friction; and if this latter horse-power be taken as a standard, the best of the engines tried by the Royal Agricultural Society this year at Cardiff will offer favourable comparison with even very good condensing-engines, and will be found to give a duty far beyond that which ten years ago would have been thought obtainable in any but the very best.

It may be mentioned that the Cornish pumping-engines, which used to be looked upon as the most economic of all engines, are, according to the June monthly report, doing only an average duty of $53\frac{3}{10}$ millions of lbs. lifted 1 foot high for 1 cwt. of coals, and that the very best of them is doing only $71\frac{7}{10}$ millions of lbs., while the break horse-power developed by Messrs. Clayton & Shuttleworth's engine, at Cardiff, gave a duty of $79\frac{2}{10}$ millions of lbs. This large duty was due to the great ability in the management of the fire (as has already been hinted at) and to the proper proportion of the boiler in obtaining the steam, and to its thorough cleaning in preserving it in the first instance, and then to the efficient utilization of that steam by high expansion in a cylinder steam-jacketed around its circumference and at the ends. But at the very same show there competed for the prize an engine which, to the eye of the uninstructed (the ordinary purchaser for example), was as likely an engine as the prize engine; and yet this engine burnt 10 lbs. of coal per horse-power per hour, or nearly four times that which was burnt by the prize engine; and, moreover, it must be remembered that this wasteful engine was one which the maker thought worthy to be sent to trial. How many are there, therefore, among those which makers do not think worthy to be sent to trial, which must deal as wastefully or more wastefully with coal, and are, for the sake of a few pounds in the first cost, bought by ignorant purchasers, who go on committing the sin of wasting coals with such engines until they are worn out, the loss becoming greater with the age of the engine.

It may be said that hitherto my observations upon consumption in steam-engines have contained quite as much of praise as of blame, and I am glad to say that it has been so; but it will be found that these praises have referred to the

engines of railways, which are under the especial charge of educated mechanical engineers, who carefully watch and tabulate all their results, and who have funds at their disposal for the purchase and maintenance of good engines—that they referred to the recent improvement in marine engines, which engines, being as a whole in the hands either of powerful companies or of large capitalists, enjoy the advantages of due outlay and of proper superintendence—and that they referred to the prize engines and to the better competitive engines of the portable class, while admitting the existence of a large number of such engines which were most wasteful of fuel. But there remains the great class of fixed engines used for driving manufactories, which engines are, as a rule, of the most disgraceful and scandalous character. In the first place, enormous numbers of them are non-condensing engines: as an excuse for this it is in many instances alleged that water is scarce and that there is not, therefore, the means of providing condensation. To meet such excuses it should be remembered there are appliances well known to scientific engineers (at all events that have been in use for many years) by which condensation can be effected with no more water than is required for the feed of a high-pressure engine. I allude to the ordinary cooling ponds for injection-water, and to the surface-evaporation condenser. In every instance these may be employed; and thus, in lieu of sending steam into the atmosphere at a pound or two above atmospheric pressure, that steam might be condensed, and a pressure of 12 or 13 lbs. additional throughout the whole stroke of the piston might be obtained; moreover the interior of the boiler would be kept clean, and thus its surface would be in the best state for transmitting heat.

But passing by this question of the repugnance to the use of condensing engines, and admitting, for the sake of argument, that non-condensing engines may be allowed, what does one ordinarily find as a type of the non-condensing engine? One finds the cylinder with a cubic capacity far too great for the work required; where steam is used throughout the stroke, one finds that this capacity is not utilized as it might be by the employment of high-pressure steam and considerable expansion, and that while the steam, even in the boiler, is probably at only 40 lbs. above atmosphere, the governor is flying out nearly to the full width, the throttle-valve is all but closed, and there is a continuous "wire drawing" of the steam, so that its average pressure throughout the stroke of the cylinder is only some 15 or 20 lbs. above atmosphere. Now when one recollects that it requires one portion of coal to get steam up to atmospheric pressure, and that this portion may be looked upon as practically constant, whatever pressure of steam above atmosphere may afterwards be attained, and that if, therefore, steam at 15 lbs. above atmosphere be used, half of all the fuel is lost, while if at 30 lbs. above atmosphere, $\frac{1}{3}$ only is lost, and if at 120 lbs. above atmosphere, $\frac{1}{9}$ only will be lost in getting up steam to atmospheric pressure, one can understand how essential it is that in non-condensing engines the steam should be used at a really high pressure; and yet, as I have said, I believe that if the large number of 10- or 20-horse horizontal non-condensing engines employed by manufacturers throughout the kingdom were examined, and indicator diagrams were taken, it would be found that their pressure upon the pistons did not average much more than 20 lbs. above atmosphere: and it is a lamentable fact that many makers of steam-engines—men who cannot be properly called engineers; men who are mere manufacturers, not knowing the principles of the art they follow—will boast that their engine is doing very well; it drives the whole of Mr. So-and-so's work and does not require more than 30 lbs. steam in the boiler, not understanding that if they would raise that steam to 120 lbs., and then work it non-expansively in a small cylinder, they would thereby be obtaining a great economy, and if they would work it expansively in a large cylinder, that cylinder being properly steam-jacketed, they would obtain a still greater economy.

I have now laid before you some of the points in which the boilers and engines of the present day are below the standard to which engineering science has already reached, and in which, therefore, there is known opportunity for immediate improvement.

I think there is so little reliable information as to the total horse-power at work in the United Kingdom (as is evidenced by the fact that very recently the number of boilers has been estimated before a Parliamentary Committee as low as 50,000,

and as high as double and even close upon quadruple that number), that I feel it would be an unwarrantable waste of the time of the Section if I were to invite them to follow me into calculations, or rather speculations, as to the exact saving that would be made in the consumption of coal consequent upon improving the whole of our steam-engines up to the present highest standard. It will, however, be quite sufficient, to show the importance of the question, for me to say (and I am sure I should be perfectly safe in saying) that such saving would have to be estimated by millions of tons.

Such a saving, as I have said, is one that might be made with our present knowledge; but when we recollect that an engine burning even as little as 2 lbs. of coal per indicated horse-power per hour is still developing only one tenth of all the power which, according to calculation, resides in that coal, there is manifestly a vast scope for our mechanical engineers in the exercise of their talents for producing further economy.

But let not users of coal remain indifferent to savings on their present consumption until those improvements are discovered by scientific men; on the contrary, let them forthwith do every thing in their power to reduce the consumption to the extent to which present science and, in some instances, present practice show the consumption can be reduced. One is apt, at first sight, to marvel that owners of steam-engines should be so blind to their own interest, and should permit waste to go on day after day and year after year—a waste not only prejudicial to the community at large and to succeeding generations, but a waste causing constant expense to those who commit it, and a waste, therefore, that one would think such persons would only be too ready to stop; but the fact is, there are several reasons why manufacturers and others permit the waste to go on.

In prosperous times those engaged in manufactures are too busy earning and saving money to attend to a reorganization of their plant; in bad times they are too dispirited and too little inclined to spend the money that in better times they have saved in replacing old and wasteful appliances by new and economical ones; and one feels that there is a very considerable amount of seeming justification for their conduct in both instances, and that it requires a really comprehensive and large intelligence and a belief in the future, possessed by only a few out of the bulk of mankind, to cause the manufacturer to pursue that which would be the true policy as well for his own interests as for those of the community. But there is a further and a perpetual bugbear in the way of such improvements, and that bugbear is the so-called "practical man;" and he was in my mind when, in previous parts of this address, I have hinted at the existence of an obstacle to the adoption of improvement.

I do not wish the Section for one moment to suppose that I, brought up as an apprentice in a workshop, and who all my life have practised my profession, intend to say one word against the truly practical man. On the contrary, he is the man of all others that I admire, and by whom I would wish persons to be guided—because the truly practical man is one who knows the reason of that which he practises, who can give an account of the faith that is in him, and who, while he possesses the readiness of mind and the dexterity which arise from the long-continued and daily intercourse with the subject of his profession, possesses also that necessary amount of theoretical and scientific knowledge which justifies him in pursuing any process he adopts, which in many cases enables him to devise new processes, or which, at all events, if he be not of an inventive quality of mind, will enable him to appreciate and value the new processes devised by others. This is the truly practical man, about whom I have nothing to say except that which is most laudatory; but the practical man as commonly understood means a man who knows the practice of his trade and knows nothing else concerning it—the man whose wisdom consists in standing by seeing, but not investigating, the new discoveries which are taking place around him, in decrying those discoveries, in applying to those who invent improvements, even the very greatest, the epithet of "schemers," and then, when he finds that, beyond all dispute, some new matter is good and has come into general practice, taking to it grumblingly, but still taking to it, because if he did not he could not compete with his co-manufacturers, the aim and object of such a man being to ensure that he should never make a mistake by embarking

his capital or his time in that which has not been proved by men of large hearts and large intelligence.

It is such a practical man as this who delays all improvement. For years he delayed the development in England of the utilization of the waste gases of blast-furnaces; and he has done so so successfully that, as I have already had occasion to remark, that utilization is by no means universal in this kingdom. It was such men as these who kept back surface-condensation for twenty years.

It is such a man as this who, when semaphores were invented, would have said, "Don't suggest such a mode to me of transmitting messages: I am a practical man, Sir; and I believe that the way to transmit a message is to write it on paper, deliver it to a messenger, and put him on horseback."

In the next generation his successor would be a believer in semaphores; and when the electrical telegraphist came to him and said, "Do you know that I can transmit movement by invisible electrical power through a wire however long? and it seems to me that, if one were to make a code out of these movements, I could speak to you at Portsmouth at one end of the wire while I was in London at the other," what would have been the answer of the practical man? "Sir, I don't believe in transmitting messages by an invisible agency; I am a practical man, and I believe in semaphores, which I can see working."

In like manner, when the Siemens's Regenerative Gas-Furnace was introduced, what said the practical man? "Turn your coals into gas, and burn the gas, and then talk of regeneration! I don't know what you mean by regeneration, except in a spiritual sense; I am a practical man, and if I want heat out of coals I put coals on to a fire and burn them:" and for fifteen years the practical man has been the bar to this most valuable improvement in metallurgical operations.

The practical man is beginning slowly to yield with respect to these furnaces, because he finds, as I have already said, that men of greater intelligence have now in sufficiently large numbers adopted the invention to make a formidable competition with the persons who stolidly refuse to be improved.

The same practical man for years stood in the way of the development of Bessemer steel. Now he has been compelled to become a convert.

I will not weary you by citing more instances; but one knows, and one's experience teaches him, that this is the conduct of the so-called practical man; and this conduct arises not only from the cause which I have given (his ignorance of the principles), but also from another cause (one which I have had occasion to allude to when speaking upon a different subject), and that is, you offend his pride when you come to him and say, "Adopt such a plan; it is an improvement on the process you carry on." His instinct revolts at the notion that you—a stranger, very likely his junior, and very probably, if the improvement be an original and radical one, a person not even connected with the trade to which that improvement relates—should dare to tell him that you can inform him of something connected with his business that he did not know.

It may be said that employers and the heads of manufactories are, as a rule, in these days, educated gentlemen, and that, therefore, it is wrong to impute to them the narrowmindedness of the practical man. I agree that in numerous instances this would be wrong; but the fact is, that in many cases (I think I may say in most cases) the head of the establishment, the monied man, the man who by his commercial ability (that most necessary element in all establishments) keeps the concern going by finding lucrative orders, is not intimately acquainted with the practice of the business carried on by his firm: he relies upon some manager or foreman, who too commonly is not the real but the so-called practical man. It is such men as those who simply practice that which they have seen, without knowing why they practice it; to them the title of practical man has most improperly been attributed; and it is on the advice of such men that the true heads of the firm too commonly regulate their conduct as to the management of their business, and as to the necessary changes to be made in the way of improvement.

As I have said, the practical man derides those who bring forward new inventions, and calls them schemers. No doubt whatever, they do scheme; and well it is for the country that there are men who do so. It also may be true that the majority of schemes prove abortive; but it must be recollected that the whole pro-

gress of art and manufacture has depended, and will depend, upon successful discoveries which in their inception were, and will be schemes, just as much as were those discoveries that have been, and will be, unfruitful; but the successful discoveries, because they are successful, are taken out of the category of schemes when years of untiring application on the part of the inventors have, so to speak, thrust them down the throat of the unwilling practical man. Take the instance of Mr. Bessemer, who was beset for years by difficulties of detail in his great scheme of improvement in the manufacture of steel. As long as he was so beset, the practical men chorused, "he is a schemer; he is one of the schemers; it is a scheme."

Supposing that these practical difficulties had beaten Mr. Bessemer, and that they had not been overcome to this day, the practical man would have derided him still as a schemer, although the theory and groundwork of his invention would have been as true under these circumstances as it now is. Fortunately for the world, and happily for him, he was able to overcome these most vexatious hindrances, and make his invention that which it is. No one now dares to apply the term "schemer" to Mr. Bessemer, or "scheme" to his invention; but it is as true now that he is a "schemer," and his invention a "scheme," as it would have been had he failed up to the present to conquer the minor difficulties. It is a species of profanation to suggest, but I must suggest it, for it is true, that Watt, Stephenson, Faraday, and almost every other name among the honoured dead to whose inventive genius we owe the development that has taken place within the last century in all the luxuries, the comforts, even the bare necessities, of our daily existence, would in their day, and while struggling for success, have been spoken of as schemers, even in respect of those very inventions of which we are now enjoying the fruits. But I feel I need not labour this point further at a Meeting of the Mechanical Section of the British Association,—an Association established for the Advancement of Science.

I know I shall be accused of decrying the practical man, and of upholding the "schemers." I say most emphatically that I do not decry the practical man. I plead guilty to the charge of decrying the miscalled practical man, and I glory in my guilt, while I readily accept that which I consider the praise of upholding "schemers;" and I do so for this simple reason, that if there were no schemers there would be no improvement.

I think it becomes a scientific body like the British Association to laud the generous efforts of the unsuccessful inventor, rather than to encourage the cold selfishness of the man who stands by and sees others endeavour to raise the structure of improvement without lending a hand to help, and even sneers at the builders, but when the structure is fully raised and solidly established, claims to come in to inhabit, and, being in, probably essays, cuckoo-like, to oust the builders and to take possession for his own benefit.

One word in conclusion. Can we not devise some means by which consumers of coal may be instructed in, shamed into, or tempted to the economical use of that most valuable material?

The Royal Agricultural Society of England, by its judicious efforts for many years past, by the institution of trials and the giving of prizes for the best engines, has brought the consumption of coal down from 10 lbs. per horse-power to a little over one quarter of that quantity.

Could we not institute a society which should devote itself to the recording and the rewarding of the performances of steamboats, and of fixed engines for land-purposes?

I am aware it is supposed there is a difficulty in these cases which does not obtain in the case of portable engines that can be brought for trial upon a dynamometer, and that is that the power exerted by marine engines varies during the voyage, and is not that which is developed at the measured mile; while in a manufactory it varies according to the conditions of the trade, and to the extent to which the British workman condescends to attend to his work.

But there are implements which record the horse-power exerted from moment to moment, and register it on indices as readable as those of an ordinary counter of an engine, or as those of a gas-meter.

I believe that one of the very greatest incentives to economical working which

the owners of steamboats could offer to their engine-builders and engineers would be the application of such implements as these. Were they employed, the ship-owner would know at the end of the voyage so much horse-power had been exerted as a whole, that so much coal had been burned, and that the result, therefore, was a consumption of so many pounds per horse-power per hour. All the effects of head-winds in retardation, and all the aid of canvas to the engine-power, would be eliminated from the calculation. The continual indicator would register truly the work the engine had to do, whether that work was made excessive by contending with head-winds, or was rendered light by favourable breezes and the assistance of canvas. In the same way the proprietor of the engine for manufacturing-purposes, the cotton-mill, the woollen-mill, the corn-mill, and even the highly irregularly working rolling-mills and saw-mills, would be able at the end of the quarter to say—"Notwithstanding all the variations of my trade and rate of manufacture, I know that my engines have exerted so much power; I know that I have burned so much coal, and that, therefore, such and such have been the economic results." Assuming that steamboat proprietors and the owners of fixed land-engines would go to the expense of applying such continuous recording implements as these to their engines, and would become members of an association for the purpose of visiting and inspecting and of reporting upon their machinery, and of giving prizes to the men in charge for careful attention, prizes to the manufacturers for original good design and workmanship of the engines, and prizes to the proprietors for their public spirit in having bought that which was good instead of that which was bad and cheap, and fo having employed intelligent and careful workmen instead of ignorant and careless ones, I believe, within a few years, as great an improvement might be seen among the marine and manufacturing class of engines as has been effected by the laudable exertions of the Royal Agricultural Society of England among the portable ones.

I think the initiation of some such society as this would be a practically useful result from the meeting of Section "G."

It now only remains for me to thank you most sincerely for the patience with which you have listened to an address that, as regards length, has exceeded the bounds within which most previous Presidents have confined themselves. My excuse is, that the subject of economy in the use of coal is in itself so highly important to every member of the community that I felt it warranted me in detaining you for a few minutes longer than the usual time.

Rapid and Economical Transport of Merchandise. *By* C. Bergeron.

The author proposes to pack the materials for transport in iron spheres of 4 feet to 6 or 7 feet diameter, and to provide a concave roadway of sheet-steel resting on sleepers, or, where necessary for crossing valleys, suspended from pillars or piers, on the principle of the suspension-bridge, down which these loaded spheres may roll by their own gravity, the empty spheres being brought back in tubes, on the principle of the pneumatic despatch.

On a Modification of the Earth-Closet. *By* D. T. Bostel.

On Aërial Navigation. *By* C. A. Bowdler.

The author thought the autumn manœuvres would be an excellent opportunity for trying experiments, and that aërostation would become an important element in military science. Hitherto captive balloons only had been used; but it was by no means improbable that circumstances would occur where it would be most desirable to pass over the enemy's position, and it would then be important to have the power of deflecting the balloon from the wind course, either to the right or to the left, as required. Captive balloons could not be used in safety in high winds, on account of violent rocking of the car. The writer then proceeded to review the

principles of aërostation, and to show that aërial navigation was practicable only to a certain limit by simple mechanical means. Of the practicability of applying steam-power he had no hope, the weight of a steam-engine made as light as possible, consistent with due strength, being much too great for any gas balloon to support. The power he proposed was manual, being, he believed, the only power applicable to gas balloons. But propulsion having been secured, the question arose how the power of direction could be acquired, that being of the utmost importance in actual warfare. That was accomplished by rotating the balloon to any required position, and then, holding it from further motion, the rotation was completely under the control of the aëronaut. A rudder was the instrument to be used for that purpose, a vertical disk fixed in a line with the axis of the propeller. By turning the plane of the disk, the current of air forced from the fan on the rudder caused the whole machine to rotate right or left, precisely as the rudder of a ship guided the vessel.

On a Modification of the Earth-Closet. *By* D. CARTER.

Progress of the Through Railway to India. *By* HYDE CLARKE, *C.E., Corr. Mem. of the Vienna Institution of Engineers.*

The progress of the railways in Turkey is of interest in connexion with the through railway to India. On this side the railway to India has long since reached Basiash on the Danube and halted there; but at length the Turkish Government had taken measures for its extension. The main line will be from Hungary through Servia to Filibeh (Philipopoli), and Edreneh (Adrianople) to Constantinople.

On account of political difficulties raised by the Servian administration, the works have been carried on at other points; but the Servian junction having been arranged operations will be begun there. The works now in progress are from Filibeh to Constantinople, with branches from Uskup to Salonika and the Mediterranean, and from Edreneh to Dedeh Aghaj on the same sea. The portions open or ready for opening are:—

Edreneh to Harmanli	40 miles.
Constantinople to Chekmejeh, &c.........	30 „
Salonika branch	65 „
Edreneh branch	90 „

The Constantinople terminus is ready.

Only 25 miles will at the end of the year remain uncompleted between Constantinople and Edreneh.

A connexion is proposed between Edreneh and the Varna and Ruschuk railway, which has a circuitous connexion with the Austro-Hungarian and Russian railways.

The Salonika branch is proposed as a steam-boat station for Smyrna, Skanderven, and the Euphrates valley and Alexandria.

No measures are taken for passing the Bosphorus at Constantinople except by steam-boat.

In the Asiatic suburb of Constantinople, at Skutari, the Asia Minor section of the through railway to India has been begun and continued to Ismid. The continuation from Ismid to Angora, 400 miles, has just been granted to Mr. Pressel, Chief Engineer of the Roumelian railways, and will be pushed with vigour.

On the Drainage of Shoreham. *By* J. P. COLBRON.

The Sewage Difficulty. *By* T. CURLEY, *F.G.S.*

On Breach-Loading Firearms. *By* C. F. DENNET.

On certain Economical Improvements in the Construction of Locomotive Engines, by the addition of Mechanical Appliances for the use of Heated Air in combination with Steam, on the principle invented by George Warsop. By RICHARD EATON.

This paper is supplementary to those read by the same author at Exeter and Liverpool, and gives the details of ably conducted and exhaustive experiments made on a locomotive, the property of the Lancashire and Yorkshire Railway Company, in regular work, mainly as a goods engine, but occasionally doing passenger-train duty in the Liverpool district. The use of the heated-air injection was found to detach old scale, of considerable thickness, from the boiler in all parts, and to prevent the formation of new, thus diminishing the item of "cost of maintenance," and prolonging the life of boilers, tubes, and fire-boxes. A great economy of fuel was also demonstrated, averaging frequently 30 per cent. The air-system was found to work in harmony with the injectors, and of great service at critical moments, such as when an engine, caught in a snow-storm, with a heavy load to draw up an incline, requires every aid to its motive power that mechanical science can give. Less coal being consumed, the atmosphere in tunnels will be purer.

On Marine Propulsion. By* W. R. ECKART *(late of U.S. Navy).*

This paper contained an account of the construction and machinery of a steam launch fitted with delicate dynamometric apparatus for testing its resistance at various speeds. It was constructed at the Navy Yard, Mare Island, California, and a very great number of careful experiments were made to determine the resistance both of the boat and of the engines. The paper was illustrated by tables and engravings.

On the Steering of Ships, in special relation to a new form of Rudder. By W. FLEMING.

Description of the New Branch Canal leading from the Canal Cavour for Irrigating the Province of Lomellina. By P. LE NEVE FOSTER, *Jun.*

The author, who had had the direction of the works, described them in considerable *technical* detail, pointing out their great importance to the productive resources of the district, not only in an agricultural point of view, but as providing considerable water-power, available for manufacturing-purposes.

Description of an Apparatus for automatically recording the Rolling of a Ship in a Seaway†. By W. FROUDE, *F.R.S.*

The fundamental principles on which the performance of the apparatus depends are:—(1) That when waves act on a ship or other floating body which would stand

* Printed in full in the Transactions of the Institution of Naval Architects for 1872, and in the 'Engineer' Newspaper for 23rd August, 1872, vol. xxxiv. p. 125.

† Mr. Froude in the discussion mentioned that, although the apparatus he had described was wholly his own invention, he had since found that a French naval architect had contrived an instrument substantially the same a few years ago, having in the first instance made the pendulum-apparatus, and then added an apparatus for observing the horizon such as he had first described. He had been in correspondence with this gentleman, and it gave him great pleasure to find that in an invention of which he had thought himself the originator he had been preceded by two or three years by a very able man. It was, however, a satisfaction to him that he was at the present time ahead of his friendly competitor in the race so far as regarded the delicately hung heavy fly-wheel which was to furnish an automatic constant record of the angles of absolute rolling, or deviations from the horizontal, assumed at each moment by the ship.

stably upright in still water, she is for the moment in equilibrium if upright or normal to the mean or effective slope of the wave which she occupies; and if she have a given righting force when inclined to a given angle in still water, she will be urged by approximately the same righting force towards the normal position in wave water if she at any moment deviate from it by the same inclination. (2) A plumb-line or pendulum, if its point of suspension be at or very near the ship's centre of gravity, will hang at rest if it occupy the normal position, and if it have a very short period of oscillation it will instantly assume that position throughout the changes of the wave-slope. The apparatus in question might be thus described. A revolving cylinder covered with paper and turned by rough clockwork received the marks made by several pens. One of these pens recorded time, jerks being given it at successive equal intervals by an exact clock. The apparatus being placed at the centre of gravity of the ship, a pendulum of very short period and considerable power, oscillating in the plane transversely with the keel, recorded continuously by a second pen the angles which the ship at each moment made with the mean or effective surface of the wave. Another pen actuated by a rocking-arm kept level by an observer on deck, who pointed it to the horizon, recorded the angle the ship made with the horizon; and from the record thus obtained the amount of the roll of the ship with regard to the wave-slope was at once shown: the form of the wave, too, could be easily worked out graphically, the wave-slope at each moment being simply the difference between the records produced by the pendulum-pen and the horizon-pen respectively. But the graphic integration of the results supplied by the pendulum-pen, if correctly performed, supplied what might be called the theoretical measure of the oscillations which the ship ought to have performed with regard to the horizon during the period embraced in the record; for the pendulum record itself supplies throughout a measure of the accelerating force by which the ship's oscillation is governed; so that the integration of this gives a diagram representing the angular velocity which the ship should theoretically have acquired under the operation of that force; and the integration of the velocity diagram in turn gives the sequence or total of motions which the varying velocity involves. The performance of these integrations involves, indeed, a correct knowledge of the ship's dynamic constants; but these, so far as they are not already known by calculation, may be readily obtained by a single experiment with the ship in still water, where, if she be artificially brought into oscillation (an operation easily performed), and the instrument be made to record the oscillations as they subside under the influence of resistance, the natural period of her oscillation is at once known, and the coefficient of resistance is deducible in a shape which is approximately applicable to the ship's seaway oscillation. All the conditions required for the integration are thus supplied. Several series of diagrams thus obtained by the oscillation of ships in a seaway had been thus integrated, and the theoretical oscillations accorded with the recorded oscillations, so that the fundamental elements of the theory of rolling had been most satisfactorily verified. An apparatus had also been completed consisting of a heavy stationary wheel, which was so delicately supported as to be incapable of receiving any rotation from the motion of a ship. This wheel, if placed transversely in the ship, would remain quite undisturbed while she rolled, and would thus supply the place of the horizontal bar above described, held level by the observer on deck. The wheel was 3 ft. in diameter and 200 lb. in weight. Through the boss was carried out a strong steel axis, the prolonged ends of which were coated with hardened steel. The axis thus prolonged rested between two pairs of rocking-arms, the ends of each pair forming a kind of V. The ends of the arms were, in fact, hardened steel plates, forming segments of circles struck from the axes or centres on which the arms rocked, so that they were virtually portions of the circumferences of very large friction-rollers. In order still further to reduce the friction of the working parts, the axes of the rocking-arms were finally reduced to hardened steel pins of small diameter, and so mounted that their motions when of small range should be rolling not sliding motions, and great delicacy was thus obtained. The centre of gravity was brought to within 0·0065 in. of the axis of suspension, and the time of a single swing was over thirty-five seconds: yet so great was the delicacy of the suspension, that a weight of $\frac{1}{2100000}$ part

of that of the wheel itself, if placed at its extreme radius, would produce an oscillation of $1\frac{1}{4}$ in. in range, and which would continue for many minutes; or if the wheel were moved 90 degrees from its position of rest, the oscillations would continue for nearly twenty minutes, the movement being so slow and solemn as to impress on the mind of an observer who had not seen it put in motion that the action was self-originated or induced by some mysterious agency. The oscillation of a ship could not put such a wheel in motion; or rather, if an infinitesimal motion were produced, this would be of so long a period that its effects would be easily separable from those proper to the oscillation of the ship. Thus the indications would be more exact than those produced by the rocking-arm on deck. The apparatus last described on deck had not yet been tried, and was awaiting a good rough day at Plymouth.

The Brighton Intercepting and Outfall Sewers. *By* JOHN G. GAMBLE, *B.A.*

Hitherto the sewage of Brighton has been partly received by cesspools, partly carried by various outfalls direct into the sea. The cesspools are being gradually abolished; but although nearly all the present outfalls now discharge under the sea beyond low-water mark, yet the nuisance to bathers and to people in boats is considerable. The intercepting sewer designed by Mr. Hawkshaw, C.E., and at present in course of construction, will intercept all the existing outfalls, and will carry the sewage away to the eastward four miles from the nearest point of Brighton, where it may either be discharged into the sea or utilized. Float experiments undertaken off Portobello prove that no nuisance can possibly be caused to Brighton.

The sewer is of circular section throughout, being of 5 feet internal diameter for nearly two miles, and 7 feet internal diameter for more than seven miles. The fall is 3 feet per mile.

At some towns the sewers are required to act as land-drains as well as sewage-carriers. This very objectionable plan is not necessary at Brighton, as the land water sinks down into the chalk, and comes out on the shore at low tide without troubling the basements of the houses. The sewer has, on the contrary, to be made especially water-tight, so as to resist the percolation from the porous strata without as well as any leakage from within. The storage capacity is such that if the whole of twelve hours' flow were penned up in the sewer it would not reach within a mile of the east end of Brighton, and any gases generated would pass up ventilating-shafts more than a mile from the town. A storm overflow and a flushing inlet will be provided. The great difficulty in managing sewers is to keep them clear of the road-sweepings, which get past the gulleys, form a solid deposit in the sewer, and collect other and more noxious materials upon them. In sewers of short length flushing by water is the best method of getting rid of such deposit; but in the case of a sewer more than seven miles long the expense of flushing the deposit forward and forward to the outfall, as well as the damage thereby done to the brick-lining, would be so great that probably the greater part of the solid materials will have to be removed by hand at the various entrances. To assist this, catch-tanks will be placed at all junctions, to stop as much as possible of the road-drift, flints, &c. that would otherwise get into the sewer. Wherever possible road-gulleys ought not to discharge into the sewers; in the front of Brighton they might, and some do, discharge on to the beach. No objection could be made to this if a good system of scavenging for horse-droppings were in operation. Ventilating-shafts are placed at intervals; they are covered by cast-iron grates made in two portions, one fitting inside the other. This is important, as a man or boy can remove the inner casting without disturbing the road metalling. He can thus get into the catch-pit with which all these shafts are provided, and clear out any road-sweepings that may have fallen through the grating. Charcoal baskets are not used, as it has been proved that they check the current of air. Charcoal will no doubt purify air that is *forced* through it, but it is only in winter when the sewer air is warmer than the air without that any great current is created. Besides, the air inside being generally cooler and therefore heavier, sulphuretted hydrogen and carbonic acid gas, two of the sewer gases, are both heavier than air; hence the only escape is

in consequence of the property gases have of diffusion. In order to create a draught, Archimedian screws worked by the wind above have been tried, but ventilation is most required when the air is calm. Fans worked by the current of water below might be used, but the worst smells are given off when the current is least. Burning the gases has been suggested; but carburetted hydrogen, one of the sewer gases, is highly inflammable, and coal-gas has been found to escape from the gas-mains into the sewers. Explosions might result; and, in fact, an explosion did result from an experiment tried by Mr. H. Austin, C.E. The same argument may be employed against the proposal to create a draught by jets of coal-gas in the shafts.

The situation of the outfall is especially suited for sewage-irrigation, and the substratum being chalk, subsoil drainage would not be required.

The Distribution of Pure Water to Dwellings. *By* ALEXANDER MCALLUM GORDON, *of Liverpool.*

This paper served to introduce a comparatively new description of piping called Haines's Lead-encased Block-tin Piping, and pointed out the advantages it offered over ordinary lead pipe as a medium for the conveyance of water throughout dwellings.

This piping consists of two distinct tubes, an outer one of lead surrounding or encasing an inner one of pure tin, both being united at their surfaces of contact as to form a perfectly homogeneous body, and thus offering the admirable physical qualities of a lead pipe together with absolute freedom from the danger of lead-poisoning by reason of the innocuous nature of the tin composing the inner pipe.

The lead-encased tin pipe was shown to be no more expensive than leaden pipe, as the extra strength gained by the superior tenacity of the tin, and certain conditions which operate in its manufacture, allows of a diminution of the weight per lineal measurement for a given pressure. The piping had already been adopted in many public institutions and private mansions throughout the kingdom, and when better known is likely to take the place of the dangerously poisonous lead pipe now so universally in use.

On Boat-lowering Apparatus. *By* E. J. HILL.

On Wire Tramways. *By* C. HODGSON.

These consist of an endless wire rope travelling over horizontal drums, one at each extremity of the distance to be traversed, supported and running over pulleys fixed on posts or piers at intervals. The buckets for holding the minerals or other goods for transport are suspended on the rope and travel with it, in such a manner as readily to pass over the pulleys and avoid contact with the posts. It appears well adapted for the transport of goods, and especially minerals, in districts where roads or ordinary tramways are not available. A working model of the wire tramway was shown at the conclusion of the meeting to the members of the Section, at Messrs. C. & J. Reed's foundry, North Road, Brighton.

Estimation of the Error in the Flight of Heavy Projectiles due to the Woolwich System of Rifling. *By* W. HOPE, *V.C.*

On the Measurement of Waves.* *By* C. W. MERRIFIELD, *F.R.S., Principal of the Royal School of Naval Architecture.*

The writer was induced to look into this matter in consequence of a question put to him by Mr. Francis Galton as to whether it was possible to arrive at any

* Printed in full in the 'Engineer' newspaper for 23rd August, 1872, vol. xxxiv. p. 119.

definite estimate of the "roughness of the sea," at present recorded for meteorological purposes at a very coarse guess from mere inspection. He considered it was desirable to confine the measurement to two points—ascertaining the aggregate height of the waves, and their number during measured intervals of time; and he had devised simple and compact machinery for this purpose, as well as for obtaining profiles of waves when desired. The machinery could consist of a float sliding up and down strained wires on a platform like Brighton or Scarborough piers. A line from this float could pass over a pulley, the motion of which, transmitted through a shaft, would give all the required measurements. The measurement of the aggregate height of the waves would be effected by simply connecting a ratchet-wheel, pawled so as only to turn one way, with the float pulley. A projecting stud on the ratchet-wheel would record the aggregate height of the waves by means of any mechanical counting arrangement. In order to count the waves, it was simply necessary to record the number of times the float pulley reversed its motion. This was effected by a reciprocating frame connected with a ratchet-wheel by a pawl, which the wheel could reverse by lifting the reciprocating frame. The method of counting which he proposed was to make a pencil which, if undisturbed, traced a straight line on a long slip of paper, such as a Morse telegraph-coil, and received a slight shake at stated numbers. Time would be marked on the same paper by a clock giving a similar shake to another pencil at stated intervals of time. In this manner a permanent and continuous record of the number of waves and aggregate height at all times would be automatically made. The machine might be perfectly boxed in, with no other communication with the external pulleys and float than a shaft passing through a stuffing-box. The recording machinery would thus be secure from injury. It would, moreover, require attention only once a day. The writer also described an arrangement by which the same machine might be made to trace the profile of waves whenever required; but this additional apparatus would require to be specially set at work when made, the waves of the sea being far too numerous for it to be possible to take portraits of all of them. Mr. Merrifield suggested that it would be very interesting to establish such an apparatus at Brighton Pier.

On the relative Value of Clarified and Unclarified Sewage as a Manure. By William Paul, *F.R.A.S.*

The author of this paper, after briefly pointing out the sources whence plants derive their food and the conditions most favourable to the free use of this food, stated that all his experience, which was considerable, was in favour of the use of "clarified" sewage, to which he attached great value.

"Now, highly important as is the use of appropriate manures to aid in the development of our growing crops, as a cultivator, I attach more importance than is commonly attached to the physical conditions of the soil—especially to keeping the surface loose and the soil porous that the water may get away, and that the air- and sun-heat may follow wherever the water or clarified sewage goes. The clarified sewage is food placed within reach of the roots; the presence of air renders this food more plentiful, and the sun-heat stimulates the roots to feed. The fertility of a soil is therefore largely influenced by the amount of air-heat which it contains.

"This brings me to the principal objection which I have to urge against putting sewage on the land in an 'unclarified' or sludgy state. I am free to admit that the sewage clarifies in its passage downwards, presenting to the roots the same food as if the sewage had been previously clarified. But the surface of the earth is thereby made to act as a filter, and the physical conditions of the soil are altered. The 'unclarified' sewage in passing through the soil has become clarified; but the pores of the soil are more or less closed against the passage of air, and a solid or half-liquid glutinous mass rests on the surface of the earth, throwing back the sun-heat! The food is there, but the stimulants of air- and sun-heat are shut out or greatly diminished, and the fertility of the soil is impaired in a corresponding degree."

The system of clarifying the sewage most strongly recommended by his experience was that of allowing it to settle by simple subsidence; the sludge is then recommended to be used by itself in a solid state.

On some Recent Improvements in the Manufacture of Artificial Stone, and the Application of such Stone to Constructive and other Purposes. By FREDERICK RANSOME, *A.I.C.E.*

The progressive development of the natural world, through periods which occurred long before the dawn of the most remote traditions of antiquity, has placed at the disposal of man materials which for the most part eminently subserve the varied purposes of construction and decoration. These materials, however, such as the granites, marbles, sandstones, limestones, &c., occur in isolated groups, in some instances so remote from the centres of civilization as to render the employment of them prohibitable for general use, excepting in local situations. The requirements of man at an early period of his history demanded a material which should approximately fulfil the conditions of stone; and this necessity was in the earlier ages supplied by the manufacture of bricks, concrete, &c. The advantages afforded by these substances were readily recognized by the ancients, and have been fully appreciated in modern times; but great as these advantages are in a constructive point of view, they fall very far short of the requirements of the present age.

It is therefore no matter for surprise that numerous attempts have been made, from time to time, to supersede the productions of nature by the imitations of art; and the importance of producing a material combining all the advantages, without having the defects, of the most useful building-stones, and possibly possessing attributes peculiarly and specifically its own, was recognized many years since by the author, who set himself the task of solving the problem of manufacturing an artificial stone which should economically answer the varied purposes of the productions of nature.

His investigations into the nature and properties of stone commenced nearly thirty years since, and he found that, with few exceptions, the hardest and most durable stones were those which contained the largest proportion of silica.

Many geologists will doubtless recollect that some years since a siliceous mineral was discovered at the base of the chalk hills in Surrey (especially in the neighbourhood of Farnham) possessing some very peculiar properties, amongst others that of being readily soluble in a solution of caustic soda, at a moderately low temperature. Taking advantage of this peculiarity, the author commenced a series of experiments, in order to determine if it were not possible, without the use of chloride of calcium, to produce a stone in all respects equal in quality to what had hitherto been done; and in this he has now succeeded.

By this latter process he combines a portion of the Farnham stone, or soluble silica, with a solution of silicate of soda or potash, lime (or substances containing lime), sand, alumina, chalk, or other convenient and suitable materials, which, when intimately mixed, are moulded into the required form as heretofore, and allowed to harden gradually, as silicate of lime is formed by the combination of the ingredients present. The mass then becomes thoroughly indurated and converted into a compact stone, capable of sustaining extraordinary pressure, and increasing in hardness with age.

The chemical actions which effect these results appear to be as under. When the materials are mixed together, the silicate of soda is decomposed, the silicic acid being liberated combines with the lime and forms a compound silicate of lime and alumina, while a portion of soda in a caustic condition is set free. This caustic soda immediately seizes upon the soluble silica (from Farnham), which constitutes one of the ingredients, and thus forms a fresh supply of silicate of soda, which is in its turn decomposed by a further quantity of lime, and so on.

If each decomposition of silicate of soda resulted in the setting free of the whole of the caustic soda, these decomposing processes would go on as long as there was any soluble silica present with which the caustic soda could combine, or until

there ceased to be any uncombined lime to decompose the silicate of soda produced, the termination of the action being marked by the presence in the pores of the stone of the excess of caustic soda in the one case, or of silicate of soda in the other. In reality, however, the whole of the caustic soda does not appear to be set free each time the silicate of soda is decomposed by the lime, there appearing to be formed a compound silicate of lime and soda, whereby a small portion of the latter is fixed at each decomposition. The result is that the caustic soda is gradually fixed, and none remains to be removed by washing or the other process.

At the age of 10 weeks, in stones made by this process, the strength as compared with Portland stone was found to be as 7145 lbs. to 2630 lbs. per square inch, and as compared with Bramley Fall 7145 lbs. to 5120 lbs., and as regards granite 7145 lbs. to 1200 lbs. per square inch. With reference to durability, it has been found practically to withstand the atmospheric changes of various climates, having been exposed to the cold of Russia and the heat and rains of India. In general appearance it bears such a perfect resemblance to the best description of natural stones as to mislead the most critical observers, whilst the facility of application and its economy in use will have been apparent from the foregoing description.

By means of this process the field has been widely extended for the application of the stone produced thereby, and which for convenience, as distinguishing it from all others, has been termed Apœnite. It is now no difficult task to produce blocks of this material of any form and of any size, the only limit being the means available for handling them upon the spot where they are to be employed. Moreover, the materials which form the bulk of apœnite are, as a rule, generally to be found in abundance where hydraulic or other important works are being carried on, and for which purposes the new stone is eminently suited.

The want of such a material for such a purpose has long been felt, although that want, until recently, has only been partially supplied. In 1870 Mr. J. W. Butler applied for and obtained a patent for improvements in the application of Concrete to Structures and Foundation, also to Cofferdams and similar constructions. Mr. Butler's obvious desire was, in the first place, to provide a cheap and efficient substitute for stone for hydraulic operations, and in the second to render unnecessary the construction of false works, &c., and thus to avoid the expense connected with the employment of iron cylinders, hitherto so extensively used. The idea was certainly an excellent one, but in realization appeared to Mr. Butler very remote, until it occurred to him that the material then introduced under the name of "apœnite" would answer the purposes of his proposed methods of construction. He accordingly communicated with the author upon the subject; and with the sanction of the engineer, a set of hollow cylinders 8 ft. in diameter and 9 in. thick were made to form a part of a retaining wall to protect the foreshore of the Thames at Hermitage Wharf, where they were accordingly sunk, and the result was satisfactory.

The application of this principle is capable of modification to suit almost every variety of construction, and it will be found especially applicable in structures requiring heavy foundations, particularly where the ground is uncertain.

For forming a face-wall in building quays or docks, instead of cylinders, rectangular hollow blocks or caissons may be used. By employing hollow blocks of hexagonal form no interstices are left, a thin layer of the cementing material rendering the structure practically homogeneous. Cylinders constructed upon this principle are also adapted for deep wells, apertures being formed in the sides for the admission of water.

Turning to works of greater magnitude, it will be seen that apœnite forms a suitable substance for the construction of bridges, sea-walls, piers, and similar undertakings. Such structures could be carried up to the underside of the bridge-girders, or built with ordinary masonry above high-water level. For sea-walls or piers another arrangement could be adopted, two rows of caissons being employed, separated from each other longitudinally, the intermediate space being filled in with dry rubble hearting, and the blocks themselves with a similar material or, if necessary, with concrete.

It would not be difficult to multiply the instances in which this material can be practically applied; but sufficient has been said on this point. An artificial stone

combining the advantages of apœnite, one, moreover, which can be so readily moulded into any form and size with but small expense and little or no delay, is necessarily applicable to a great variety of uses. The author then made a few brief remarks upon its applicability for ornamental and decorative purposes.

Besides possessing the several properties which have been described, the apœnite, when prepared with suitable materials, is capable of receiving the most delicate impressions, and by the incorporation of various metallic oxides, any variety of colour can be imparted to it.

By the use of the native red oxide of iron, manganese, and other mineral substances, artificial marble or granite of almost every description can be produced. These artificial stones, like their originals, are capable of taking an excellent polish, are extremely hard, and can be readily moulded into the most elaborate forms, at a very small cost.

In conclusion, the author submits that, both constructively and ornamentally, apœnite is eminently fitted to meet the numerous requirements of the engineer and architect, and to subserve many useful and important purposes in the industrial arts.

On Defecating Sewage and Utilizing the Deposit for the preparation of Lime and Cement. By Maj.-Gen. H. Y. D. Scott, *C.B.*

On the Agricultural Value of the Lime Compounds obtained by Defecating Sewage. By Maj.-Gen. H. Y. D. Scott, *C.B.*

On the Selenitic Method of making Mortar. By Maj.-Gen. H. Y. D. Scott, *C.B.*

On an Apparatus for testing the Water-stopping efficiency of Clay Soils and other Substances under various pressures. By John Smyth, *Jun., A.M., M.I.C.E.I.*

The author, when engaged in 1867 in repairing a leak in the principal embankment of the reservoir for supplying the river Bann in Ireland (see Transactions of the Institution of Civil Engineers of Ireland, vol. ix. page 51, "An Historical Sketch of the Construction, Working, and Repair of the Bann Reservoir"), was obliged to make experiments on the capabilities of peat, clays, and soils in stanching water, and felt the want of an efficient apparatus for the purpose. Subsequently, after making more experiments, he was led to devise the apparatus of which a diagram was exhibited. The instrument consists of a cylindrical chamber 6 inches in diameter, 3 feet deep, provided at the bottom with a perforated plate, which allows all leakage to pass away, and at the top with another plate into which is screwed a 1 inch in diameter iron pipe, made of such length as the position of the instrument and the pressure to be experimented with will allow. Two narrow glass windows, 2 feet long by $\frac{1}{2}$ inch wide, are provided on opposite sides of the cylinder, by which to observe the behaviour of the substance under experiment First a layer of gravel is put in to cover the holes in the bottom plate, next the experimental substance is rammed in, and next another layer of gravel. The author has tried experiments on 1 foot deep of peat, and found that although at first the leakage is increased by increase of pressure, yet when the pressure is kept constant it soon diminishes even with clear water; in new embankments the water passing through would be muddy, and likely to diminish the leakage much sooner. The author intends to make more experiments, and in the mean time commended the instrument to the notice of the Section as likely to be useful to those engaged in the construction of waterworks.

On a Plan for Railway Amalgamation with Government Control.
By W. Symons, *F.C.S.*

The author stated the objections both to extensive amalgamations and to Government purchase and management, and suggested that the evils of both could be avoided, and the advantages hoped for from each secured, by blending the two schemes. Our railways should be arranged in six or more groups, and the numerous classes of shares, stock, &c. in each group be reduced by a commission of actuaries, partly to debentures bearing a fixed interest, but the larger portion to ordinary stock on which the Government should guarantee a minimum dividend.

The majority of the Directors to be still elected by the Shareholders, but a few nominated by the Board of Trade, and perhaps some by the large towns and counties interested. The Directors would have a substantial motive for efficient and economical management in keeping the dividend above the guaranteed minimum; but the Board of Trade would fix the tariff both for passengers and goods, and should try the experiment of greatly reduced fares. A central Council elected by the various Boards of Directors, with some members selected by the Board of Trade, could supervise the whole. Such a scheme would secure the following advantages:—1st, the public would gain safer, cheaper, and better-arranged conveyances; 2nd, the management of the property would still be with the Directors, the majority of whom would be elected by the Shareholders; 3rd, a vast saving would result from more economical and harmonious working; 4th, the property of the Shareholder would always maintain a certain value; and 5th, the public, through the Government, without purchasing the railways, would have a real and efficient control over the whole system, but this could not degenerate into a system of patronage and jobbing. Necessary arrangements for new lines and extensions are alluded to, and the author suggests that an introduction of American carriages would be cheaper and safer and dispense with the necessity of signals.

On the use of Steel Wire for Deep-sea Soundings.
By Prof. Sir W. Thomson, *LL.D., F.R.S.*

The wire used is pianoforte wire of 22 gauge, which is less cumbersome and heavy and acts with less friction than the hempen line now used. It needs not the heavy mass of iron, weighing from two to four hundredweight, hitherto employed to sink it, 30 lbs. being amply sufficient for sounding in 3000 fathoms. It is paid out rapidly from a small drum controlled by a simple break composed of a cord fixed at one end, and with a weight of from 10 lbs. to 60 lbs. at the other, passing once and a half round the drum. It is easily and quickly drawn up, contrasting most advantageously in rapidity and power required with the old system. The steel is preserved from rusting by the use of powdered lime, or by keeping the drum in oil when not in use.

On the Identification of Lights at Sea.
By Prof. Sir W. Thomson, *LL.D., F.R.S.*

The author drew the attention of the Section to the extreme importance of ready identification of lights at sea; and he pointed out how difficult it is, under the present system of lighthouses, to distinguish one lighthouse from another. The means now adopted of slow revolving lights, with different periods, were wholly inadequate, and were constantly leading to error and sometimes to disaster. He proposed the use of flashing lights, the flash being of longer or shorterduration, the short and long flashes representing the dot and dash of the Morse alphabet now used for telegraphing. Each lighthouse should signal its own letter, and would thus be readily and rapidly distinguished. Such a system was now used regularly in the navy for the transmission of messages at sea; and as what he proposed involved only the signalling of a single letter, he considered there need be no difficulty in its adoption, and he thought that the subject should be pressed strongly on the Government.

On Drilling-Apparatus for Gas- and Water-Mains. By A. Upward.

On the advancement of Science due to Patented Inventions. By Thomas Webster, *Q.C., M.A., F.R.S.*

In this communication attention is directed to the contributions due to the labour expended on inventions which have been the subject of patents as illustrative of the position that "art is the mother of science." The benefits which the practical or industrial arts have derived from the discoveries of science, as of modern chemistry, is not denied; but the author points to photography, vulcanized rubber, Siemens's furnaces, Bessemer "steel," Ransome "stone," &c. as instances in which art has preceded science, in results of which no adequate explanation can be given. It is suggested that the above would form a proper subject of inquiry and report by a Committee of the Association.

On the Progress of Invention in Breech-loading Small Arms during the past Twenty Years. By A. Wylie.

All the inventions in breech-loading firearms since 1851 presenting any novelty were reviewed and grouped in their natural connexion, so as to trace the development of each system down to the present time. The Reports of the Small Arms Committee were criticized and their conclusions disputed; and it was shown that their decision arrived at three and a half years ago had had the evil effect of putting almost a complete stop to invention in any direction except in that of the chosen arm, the ingenuity of the inventors and manufacturers being now expended in hopeless attempts to improve the Martini.

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Rev. J. Challis, on Capillary Attraction;—Prof. Lloyd, on Physical Optics;—G. Rennie, on Hydraulics, Part II.

Together with the Transactions of the Sections, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FIFTH MEETING, at Dublin, 1835, *Published at 13s. 6d.*

CONTENTS:—Rev. W. Whewell, on the Recent Progress and Present Condition of the Mathematical Theories of Electricity, Magnetism, and Heat; — A. Quetelet, Aperçu de l'Etat actuel des Sciences Mathématiques chez les Belges;—Capt. E. Sabine, on the Phenomena of Terrestrial Magnetism.

Together with the Transactions of the Sections, Prof. Sir W. Hamilton's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE SIXTH MEETING, at Bristol, 1836, *Published at 12s.*

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PROCEEDINGS OF THE SEVENTH MEETING, at Liverpool, 1837, *Published at 16s. 6d.*

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nel to the English Channel, by Mr. Bunt;—Report on the Discussions of Tides, prepared under the direction of the Rev. W. Whewell;—W. S. Harris, Account of the Progress and State of the Meteorological Observations at Plymouth;—Major E. Sabine, on the Magnetic Isoclinal and Isodynamic Lines in the British Islands;—D. Lardner, LL.D., on the Determination of the Mean Numerical Values of Railway Constants;—R. Mallet, First Report upon Experiments upon the Action of Sea and River Water upon Cast and Wrought Iron;—R. Mallet, on the Action of a Heat of 212° Fahr., when long continued, on Inorganic and Organic Substances.

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Together with the Transactions of the Sections, Lord Francis Egerton's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTEENTH MEETING, at Cork, 1843, *Published at* 12*s*.

CONTENTS:—Robert Mallet, Third Report upon the Action of Air and Water, whether fresh or salt, clear or foul, and at Various Temperatures, upon Cast Iron, Wrought Iron, and Steel;—Report of the Committee appointed to conduct the cooperation of the British Association in the System of Simultaneous Magnetical and Meteorological Observations;—Sir J. F. W. Herschel, Bart., Report of the Committee appointed for the Reduction of Meteorological Observations;—Report of the Committee appointed for Experiments on Steam-Engines;—Report of the Committee appointed to continue their Experiments on the Vitality of Seeds;—J. S. Russell, Report of a Series of Observations on the Tides of the Frith of Forth and the East Coast of Scotland;—J. S. Russell, Notice of a Report of the Committee on the Form of Ships;—J. Blake, Report on the Physiological Action of Medicines;—Report of the Committee on Zoological Nomenclature;—Report of the Committee for Registering the Shocks of Earthquakes, and making such Meteorological Observations as may appear to them desirable;—Report of the Committee for conducting Experiments with Captive Balloons;—Prof. Wheatstone, Appendix to the Report;—Report of the Committee for the Translation and Publication of Foreign Scientific Memoirs;—C. W. Peach, on the Habits of the Marine Testacea;—E. Forbes, Report on the Mollusca and Radiata of the Ægean Sea, and on their distribution, considered as bearing on Geology;—L. Agassiz, Synoptical Table of British Fossil Fishes, arranged in the order of the Geological Formations;—R. Owen, Report on the British Fossil Mammalia, Part II.;—E. W. Binney, Report on the excavation made at the junction of the Lower New Red Sandstone with the Coal Measures at Collyhurst;—W.

Thompson, Report on the Fauna of Ireland: Div. *Invertebrata*;—Provisional Reports, and Notices of Progress in Special Researches entrusted to Committees and Individuals.

Together with the Transactions of the Sections, Earl of Rosse's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FOURTEENTH MEETING, at York, 1844, *Published at £1.*

CONTENTS:—W. B. Carpenter, on the Microscopic Structure of Shells;—J. Alder and A. Hancock, Report on the British Nudibranchiate Mollusca;—R. Hunt, Researches on the Influence of Light on the Germination of Seeds and the Growth of Plants;—Report of a Committee appointed by the British Association in 1840, for revising the Nomenclature of the Stars;—Lt.-Col. Sabine, on the Meteorology of Toronto in Canada;—J. Blackwall, Report on some recent researches into the Structure, Functions, and Economy of the *Araneidea* made in Great Britain;—Earl of Rosse, on the Construction of large Reflecting Telescopes; —Rev. W. V. Harcourt, Report on a Gas-furnace for Experiments on Vitrifaction and other Applications of High Heat in the Laboratory;—Report of the Committee for Registering Earthquake Shocks in Scotland;—Report of a Committee for Experiments on Steam-Engines; —Report of the Committee to investigate the Varieties of the Human Race;—Fourth Report of a Committee appointed to continue their Experiments on the Vitality of Seeds;—W. Fairbairn, on the Consumption of Fuel and the Prevention of Smoke;—F. Ronalds, Report concerning the Observatory of the British Association at Kew;—Sixth Report of the Committee appointed to conduct the Cooperation of the British Association in the System of Simultaneous Magnetical and Meteorological Observations;—Prof. Forchhammer on the influence of Fucoidal Plants upon the Formations of the Earth, on Metamorphism in general, and particularly the Metamorphosis of the Scandinavian Alum Slate;—H. E. Strickland, Report on the recent Progress and Present State of Ornithology;—T. Oldham, Report of Committee appointed to conduct Observations on Subterranean Temperature in Ireland;—Prof. Owen, Report on the Extinct Mammals of Australia, with descriptions of certain Fossils indicative of the former existence in that continent of large Marsupial Representatives of the Order Pachydermata;—W. S. Harris, Report on the working of Whewell and Osler's Anemometers at Plymouth, for the years 1841, 1842, 1843;—W. R. Birt, Report on Atmospheric Waves; —L. Agassiz, Rapport sur les Poissons Fossiles de l'Argile de Londres, with translation;—J. S. Russell, Report on Waves;—Provisional Reports, and Notices of Progress in Special Researches entrusted to Committees and Individuals.

Together with the Transactions of the Sections, Dean of Ely's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FIFTEENTH MEETING, at Cambridge, 1845, *Published at 12s.*

CONTENTS:—Seventh Report of a Committee appointed to conduct the Cooperation of the British Association in the System of Simultaneous Magnetical and Meteorological Observations;—Lt.-Col. Sabine, on some points in the Meteorology of Bombay;—J. Blake, Report on the Physiological Actions of Medicines;—Dr. Von Boguslawski, on the Comet of 1843; —R. Hunt, Report on the Actinograph;—Prof. Schönbein, on Ozone;—Prof. Erman, on the Influence of Friction upon Thermo-Electricity;—Baron Senftenberg, on the Self-Registering Meteorological Instruments employed in the Observatory at Senftenberg;—W. R. Birt, Second Report on Atmospheric Waves;—G. R. Porter, on the Progress and Present Extent of Savings' Banks in the United Kingdom;—Prof. Bunsen and Dr. Playfair, Report on the Gases evolved from Iron Furnaces, with reference to the Theory of Smelting of Iron;—Dr. Richardson, Report on the Ichthyology of the Seas of China and Japan;—Report of the Committee on the Registration of Periodical Phenomena of Animals and Vegetables;—Fifth Report of the Committee on the Vitality of Seeds;—Appendix, &c.

Together with the Transactions of the Sections, Sir J. F. W. Herschel's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE SIXTEENTH MEETING, at Southampton, 1846, *Published at 15s.*

CONTENTS:—G. G. Stokes, Report on Recent Researches in Hydrodynamics;—Sixth Report of the Committee on the Vitality of Seeds;—Dr. Schunck, on the Colouring Matters of Madder;—J. Blake, on the Physiological Action of Medicines;—R. Hunt, Report on the Actinograph;—R. Hunt, Notices on the Influence of Light on the Growth of Plants;—R. L. Ellis, on the Recent Progress of Analysis;—Prof. Forchhammer, on Comparative Analytical

Researches on Sea Water;—A. Erman, on the Calculation of the Gaussian Constants for 1829;—G. R. Porter, on the Progress, present Amount, and probable future Condition of the Iron Manufacture in Great Britain;—W. R. Birt, Third Report on Atmospheric Waves;—Prof. Owen, Report on the Archetype and Homologies of the Vertebrate Skeleton;—J. Phillips, on Anemometry;—J. Percy, M.D., Report on the Crystalline Flags;—Addenda to Mr. Birt's Report on Atmospheric Waves.

Together with the Transactions of the Sections, Sir R. I. Murchison's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE SEVENTEENTH MEETING, at Oxford, 1847, *Published at* 18s.

CONTENTS:—Prof. Langberg, on the Specific Gravity of Sulphuric Acid at different degrees of dilution, and on the relation which exists between the Development of Heat and the coincident contraction of Volume in Sulphuric Acid when mixed with Water;—R. Hunt, Researches on the Influence of the Solar Rays on the Growth of Plants;—R. Mallet, on the Facts of Earthquake Phenomena;—Prof. Nilsson, on the Primitive Inhabitants of Scandinavia;—W. Hopkins, Report on the Geological Theories of Elevation and Earthquakes;—Dr. W. B. Carpenter, Report on the Microscopic Structure of Shells;—Rev. W. Whewell and Sir James C. Ross, Report upon the Recommendation of an Expedition for the purpose of completing our knowledge of the Tides;—Dr. Schunck, on Colouring Matters;—Seventh Report of the Committee on the Vitality of Seeds;—J. Glynn, on the Turbine or Horizontal Water-Wheel of France and Germany;—Dr R. G. Latham, on the present state and recent progress of Ethnographical Philology;—Dr. J. C. Prichard, on the various methods of Research which contribute to the Advancement of Ethnology, and of the relations of that Science to other branches of Knowledge;—Dr. C. C. J. Bunsen, on the results of the recent Egyptian researches in reference to Asiatic and African Ethnology, and the Classification of Languages;—Dr. C. Meyer, on the Importance of the Study of the Celtic Language as exhibited by the Modern Celtic Dialects still extant;—Dr. Max Müller, on the Relation of the Bengali to the Arian and Aboriginal Languages of India;—W. R. Birt, Fourth Report on Atmospheric Waves;—Prof. W. H. Dove, Temperature Tables, with Introductory Remarks by Lieut.-Col. E. Sabine;—A. Erman and H. Petersen, Third Report on the Calculation of the Gaussian Constants for 1829.

Together with the Transactions of the Sections, Sir Robert Harry Inglis's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE EIGHTEENTH MEETING, at Swansea, 1848, *Published at* 9s.

CONTENTS:—Rev. Prof. Powell, A Catalogue of Observations of Luminous Meteors;—J. Glynn on Water-pressure Engines;—R. A. Smith, on the Air and Water of Towns;—Eighth Report of Committee on the Growth and Vitality of Seeds;—W. R. Birt, Fifth Report on Atmospheric Waves;—E. Schunck, on Colouring Matters;—J. P. Budd, on the advantageous use made of the gaseous escape from the Blast Furnaces at the Ystalyfera Iron Works;—R. Hunt, Report of progress in the investigation of the Action of Carbonic Acid on the Growth of Plants allied to those of the Coal Formations;—Prof. H. W. Dove, Supplement to the Temperature Tables printed in the Report of the British Association for 1847;—Remarks by Prof. Dove on his recently constructed Maps of the Monthly Isothermal Lines of the Globe, and on some of the principal Conclusions in regard to Climatology deducible from them; with an introductory Notice by Lt.-Col. E. Sabine;—Dr. Daubeny, on the progress of the investigation on the Influence of Carbonic Acid on the Growth of Ferns;—J. Phillips, Notice of further progress in Anemometrical Researches;—Mr. Mallet's Letter to the Assistant-General Secretary;—A. Erman, Second Report on the Gaussian Constants;—Report of a Committee relative to the expediency of recommending the continuance of the Toronto Magnetical and Meteorological Observatory until December 1850.

Together with the Transactions of the Sections, the Marquis of Northampton's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE NINETEENTH MEETING, at Birmingham, 1849, *Published at* 10s.

CONTENTS:—Rev. Prof. Powell, A Catalogue of Observations of Luminous Meteors;—Earl of Rosse, Notice of Nebulæ lately observed in the Six-feet Reflector;—Prof. Daubeny, on the Influence of Carbonic Acid Gas on the health of Plants, especially of those allied to the Fossil Remains found in the Coal Formation;—Dr. Andrews, Report on the Heat of Combination;—Report of the Committee on the Registration of the Periodic Phenomena of Plants and

Animals;—Ninth Report of Committee on Experiments on the Growth and Vitality of Seeds; —F. Ronalds, Report concerning the Observatory of the British Association at Kew, from Aug. 9, 1848 to Sept. 12, 1849;—R. Mallet, Report on the Experimental Inquiry on Railway Bar Corrosion;—W. R. Birt, Report on the Discussion of the Electrical Observations at Kew.

Together with the Transactions of the Sections, the Rev. T. R. Robinson's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTIETH MEETING, at Edinburgh, 1850, *Published at 15s.* (Out of Print.)

CONTENTS:—R. Mallet, First Report on the Facts of Earthquake Phenomena;—Rev. Prof. Powell, on Observations of Luminous Meteors;—Dr. T. Williams, on the Structure and History of the British Annelida;—T. C. Hunt, Results of Meteorological Observations taken at St. Michael's from the 1st of January, 1840 to the 31st of December, 1849;—R. Hunt, on the present State of our Knowledge of the Chemical Action of the Solar Radiations;—Tenth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Major-Gen. Briggs, Report on the Aboriginal Tribes of India;—F. Ronalds, Report concerning the Observatory of the British Association at Kew;—E. Forbes, Report on the Investigation of British Marine Zoology by means of the Dredge;—R. MacAndrew, Notes on the Distribution and Range in depth of Mollusca and other Marine Animals, observed on the coasts of Spain, Portugal, Barbary, Malta, and Southern Italy in 1849;—Prof. Allman, on the Present State of our Knowledge of the Freshwater Polyzoa;—Registration of the Periodical Phenomena of Plants and Animals;—Suggestions to Astronomers for the Observation of the Total Eclipse of the Sun on July 28, 1851.

Together with the Transactions of the Sections, Sir David Brewster's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-FIRST MEETING, at Ipswich, 1851, *Published at 16s. 6d.*

CONTENTS:—Rev. Prof. Powell, on Observations of Luminous Meteors;—Eleventh Report of Committee on Experiments on the Growth and Vitality of Seeds;—Dr. J. Drew, on the Climate of Southampton;—Dr. R. A. Smith, on the Air and Water of Towns: Action of Porous Strata, Water and Organic Matter;—Report of the Committee appointed to consider the probable Effects in an Economical and Physical Point of View of the Destruction of Tropical Forests;—A. Henfrey, on the Reproduction and supposed Existence of Sexual Organs in the Higher Cryptogamous Plants;—Dr. Daubeny, on the Nomenclature of Organic Compounds;—Rev. Dr. Donaldson, on two unsolved Problems in Indo-German Philology;—Dr. T. Williams, Report on the British Annelida;—R. Mallet, Second Report on the Facts of Earthquake Phenomena;—Letter from Prof. Henry to Col. Sabine, on the System of Meteorological Observations proposed to be established in the United States;—Col. Sabine, Report on the Kew Magnetographs;—J. Welsh, Report on the Performance of his three Magnetographs during the Experimental Trial at the Kew Observatory;—F. Ronalds, Report concerning the Observatory of the British Association at Kew, from September 12, 1850 to July 31, 1851;—Ordnance Survey of Scotland.

Together with the Transactions of the Sections, Prof. Airy's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-SECOND MEETING, at Belfast, 1852, *Published at 15s.*

CONTENTS:—R. Mallet, Third Report on the Facts of Earthquake Phenomena;—Twelfth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1851–52;—Dr. Gladstone, on the Influence of the Solar Radiations on the Vital Powers of Plants;—A Manual of Ethnological Inquiry;—Col. Sykes, Mean Temperature of the Day, and Monthly Fall of Rain at 127 Stations under the Bengal Presidency;—Prof. J. D. Forbes, on Experiments on the Laws of the Conduction of Heat;—R. Hunt, on the Chemical Action of the Solar Radiations;—Dr. Hodges, on the Composition and Economy of the Flax Plant;—W. Thompson, on the Freshwater Fishes of Ulster;—W. Thompson, Supplementary Report on the Fauna of Ireland;—W. Wills, on the Meteorology of Birmingham;—J. Thomson, on the Vortex-Water-Wheel;—J. B. Lawes and Dr. Gilbert, on the Composition of Foods in relation to Respiration and the Feeding of Animals.

Together with the Transactions of the Sections, Colonel Sabine's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-THIRD MEETING, at Hull, 1853, *Published at* 10*s*. 6*d*.

CONTENTS:—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1852–53;—James Oldham, on the Physical Features of the Humber;—James Oldham, on the Rise, Progress, and Present Position of Steam Navigation in Hull;—William Fairbairn, Experimental Researches to determine the Strength of Locomotive Boilers, and the causes which lead to Explosion;—J. J. Sylvester, Provisional Report on the Theory of Determinants;—Professor Hodges, M.D., Report on the Gases evolved in Steeping Flax, and on the Composition and Economy of the Flax Plant;—Thirteenth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Robert Hunt, on the Chemical Action of the Solar Radiations;—John P. Bell, M.D., Observations on the Character and Measurements of Degradation of the Yorkshire Coast; First Report of Committee on the Physical Character of the Moon's Surface, as compared with that of the Earth;—R. Mallet, Provisional Report on Earthquake Wave-Transits; and on Seismometrical Instruments;—William Fairbairn, on the Mechanical Properties of Metals as derived from repeated Meltings, exhibiting the maximum point of strength and the causes of deterioration;—Robert Mallet, Third Report on the Facts of Earthquake Phenomena (continued).

Together with the Transactions of the Sections, Mr. Hopkins's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-FOURTH MEETING, at Liverpool, 1854, *Published at* 18*s*.

CONTENTS:—R. Mallet, Third Report on the Facts of Earthquake Phenomena (continued);—Major-General Chesney, on the Construction and General Use of Efficient Life-Boats;—Rev. Prof. Powell, Third Report on the present State of our Knowledge of Radiant Heat;—Colonel Sabine, on some of the results obtained at the British Colonial Magnetic Observatories;—Colonel Portlock, Report of the Committee on Earthquakes, with their proceedings respecting Seismometers;—Dr. Gladstone, on the influence of the Solar Radiations on the Vital Powers of Plants, Part 2;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1853–54;—Second Report of the Committee on the Physical Character of the Moon's Surface;—W. G. Armstrong, on the Application of Water-Pressure Machinery;—J. B. Lawes and Dr. Gilbert, on the Equivalency of Starch and Sugar in Food;—Archibald Smith, on the Deviations of the Compass in Wooden and Iron Ships;—Fourteenth Report of Committee on Experiments on the Growth and Vitality of Seeds.

Together with the Transactions of the Sections, the Earl of Harrowby's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-FIFTH MEETING, at Glasgow, 1855, *Published at* 15*s*.

CONTENTS:—T. Dobson, Report on the Relation between Explosions in Coal-Mines and Revolving Storms;—Dr. Gladstone, on the Influence of the Solar Radiations on the Vital Powers of Plants growing under different Atmospheric Conditions, Part 3;—C. Spence Bate, on the British Edriophthalma;—J. F. Bateman, on the present state of our knowledge on the Supply of Water to Towns;—Fifteenth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1854–55;—Report of Committee appointed to inquire into the best means of ascertaining those properties of Metals and effects of various modes of treating them which are of importance to the durability and efficiency of Artillery;—Rev. Prof. Henslow, Report on Typical Objects in Natural History;—A. Follett Osler, Account of the Self-Registering Anemometer and Rain-Gauge at the Liverpool Observatory;—Provisional Reports.

Together with the Transactions of the Sections, the Duke of Argyll's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-SIXTH MEETING, at Cheltenham, 1856, *Published at* 18*s*.

CONTENTS:—Report from the Committee appointed to investigate and report upon the effects produced upon the Channels of the Mersey by the alterations which within the last fifty years have been made in its Banks;—J. Thomson, Interim Report on progress in Researches on the Measurement of Water by Weir Boards;—Dredging Report, Frith of Clyde, 1856;—Rev. B. Powell, Report on Observations of Luminous Meteors, 1855–1856;—Prof. Bunsen and Dr. H. E. Roscoe, Photochemical Researches;—Rev. James Booth, on the Trigonometry of the Parabola, and the Geometrical Origin of Logarithms;—R. MacAndrew, Report

on the Marine Testaceous Mollusca of the North-east Atlantic and Neighbouring Seas, and the physical conditions affecting their development;—P. P. Carpenter, Report on the present state of our knowledge with regard to the Mollusca of the West Coast of North America;—T. C. Eyton, Abstract of First Report on the Oyster Beds and Oysters of the British Shores;—Prof. Phillips, Report on Cleavage and Foliation in Rocks, and on the Theoretical Explanations of these Phenomena: Part I.;—Dr. T. Wright on the Stratigraphical Distribution of the Oolitic Echinodermata;—W. Fairbairn, on the Tensile Strength of Wrought Iron at various Temperatures;—C. Atherton, on Mercantile Steam Transport Economy;—J. S. Bowerbank, on the Vital Powers of the Spongiadæ;—Report of a Committee upon the Experiments conducted at Stormontfield, near Perth, for the artificial propagation of Salmon;—Provisional Report on the Measurement of Ships for Tonnage;—On Typical Forms of Minerals, Plants and Animals for Museums;—J. Thomson, Interim Report on Progress in Researches on the Measurement of Water by Weir Boards;—R. Mallet, on Observations with the Seismometer;—A. Cayley, on the Progress of Theoretical Dynamics;—Report of a Committee appointed to consider the formation of a Catalogue of Philosophical Memoirs.

Together with the Transactions of the Sections, Dr. Daubeny's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS of the TWENTY-SEVENTH MEETING, at Dublin, 1857, *Published at* 15*s.*

Contents:—A. Cayley, Report on the Recent Progress of Theoretical Dynamics;—Sixteenth and final Report of Committee on Experiments on the Growth and Vitality of Seeds;—James Oldham, C.E., continuation of Report on Steam Navigation at Hull;—Report of a Committee on the Defects of the present methods of Measuring and Registering the Tonnage of Shipping, as also of Marine Engine-Power, and to frame more perfect rules, in order that a correct and uniform principle may be adopted to estimate the Actual Carrying Capabilities and Working-Power of Steam Ships;—Robert Were Fox, Report on the Temperature of some Deep Mines in Cornwall;—Dr. G. Plarr, De quelques Transformations de la Somme $\Sigma_0^{-\alpha} t \frac{\alpha^{t|+1}\beta^{t|+1}\delta^{t|+1}}{1^{t|+1}\gamma^{t|+1}\epsilon^{t|+1}}$, α étant entier négatif, et de quelques cas dans lesquels cette somme est exprimable par une combinaison de factorielles, la notation $\alpha^{t|+1}$ désignant le produit des t facteurs $\alpha\ (\alpha+1)\ (\alpha+2)$ &c....$(\alpha+t-1)$;—G Dickie, M.D., Report on the Marine Zoology of Strangford Lough, County Down, and corresponding part of the Irish Channel;—Charles Atherton, Suggestions for Statistical Inquiry into the extent to which Mercantile Steam Transport Economy is affected by the Constructive Type of Shipping, as respects the Proportions of Length, Breadth, and Depth;—J. S. Bowerbank, Further Report on the Vitality of the Spongiadæ;—John P. Hodges, M.D., on Flax;—Major-General Sabine, Report of the Committee on the Magnetic Survey of Great Britain;—Rev. Baden Powell, Report on Observations of Luminous Meteors, 1856–57;—C. Vignoles, C.E., on the Adaptation of Suspension Bridges to sustain the passage of Railway Trains;—Professor W. A. Miller, M.D., on Electro-Chemistry;—John Simpson, R.N., Results of Thermometrical Observations made at the 'Plover's' Wintering-place, Point Barrow, latitude 71° 21′ N., long. 156° 17′ W., in 1852–54;—Charles James Hargreave, LL.D., on the Algebraic Couple; and on the Equivalents of Indeterminate Expressions;—Thomas Grubb, Report on the Improvement of Telescope and Equatorial Mountings;—Professor James Buckman, Report on the Experimental Plots in the Botanical Garden of the Royal Agricultural College at Cirencester;—William Fairbairn on the Resistance of Tubes to Collapse;—George C. Hyndman, Report of the Proceedings of the Belfast Dredging Committee;—Peter W. Barlow, on the Mechanical Effect of combining Girders and Suspension Chains, and a Comparison of the Weight of Metal in Ordinary and Suspension Girders, to produce equal deflections with a given load;—J. Park Harrison, M.A., Evidences of Lunar Influence on Temperature;—Report on the Animal and Vegetable Products imported into Liverpool from the year 1851 to 1855 (inclusive);—Andrew Henderson, Report on the Statistics of Life-boats and Fishing-boats on the Coasts of the United Kingdom.

Together with the Transactions of the Sections, Rev. H. Lloyd's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS of the TWENTY-EIGHTH MEETING, at Leeds, September 1858, *Published at* 20*s.*

Contents:—R. Mallet, Fourth Report upon the Facts and Theory of Earthquake Phenomena;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1857–58;—R. H. Meade, on some Points in the Anatomy of the Araneidea or true Spiders, especially on the internal structure of their Spinning Organs;—W. Fairbairn, Report of the Committee on the Patent Laws;—S. Eddy, on the Lead Mining Districts of Yorkshire;—W. Fairbairn, on the

Collapse of Glass Globes and Cylinders;—Dr. E. Perceval Wright and Prof. J. Reay Greene, Report on the Marine Fauna of the South and West Coasts of Ireland;—Prof. J. Thomson, on Experiments on the Measurement of Water by Triangular Notches in Weir Boards;—Major-General Sabine, Report of the Committee on the Magnetic Survey of Great Britain;—Michael Connal and William Keddie, Report on Animal, Vegetable, and Mineral Substances imported from Foreign Countries into the Clyde (including the Ports of Glasgow, Greenock, and Port Glasgow) in the years 1853, 1854, 1855, 1856, and 1857;—Report of the Committee on Shipping Statistics;—Rev. H. Lloyd, D.D., Notice of the Instruments employed in the Magnetic Survey of Ireland, with some of the Results;—Prof. J. R. Kinahan, Report of Dublin Dredging Committee, appointed 1857–58;—Prof. J. R. Kinahan, Report on Crustacea of Dublin District;—Andrew Henderson, on River Steamers, their Form, Construction, and Fittings, with reference to the necessity for improving the present means of Shallow-Water Navigation on the Rivers of British India;—George C. Hyndman, Report of the Belfast Dredging Committee;—Appendix to Mr. Vignoles's paper "On the Adaptation of Suspension Bridges to sustain the passage of Railway Trains;"—Report of the Joint Committee of the Royal Society and the British Association, for procuring a continuance of the Magnetic and Meteorological Observatories;—R. Beckley, Description of a Self-recording Anemometer.

Together with the Transactions of the Sections, Prof. Owen's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-NINTH MEETING, at Aberdeen, September 1859, *Published at 15s.*

CONTENTS:—George C. Foster, Preliminary Report on the Recent Progress and Present State of Organic Chemistry;—Professor Buckman, Report on the Growth of Plants in the Garden of the Royal Agricultural College, Cirencester;—Dr. A. Voelcker, Report on Field Experiments and Laboratory Researches on the Constituents of Manures essential to cultivated Crops;—A. Thomson, Esq., of Banchory, Report on the Aberdeen Industrial Feeding Schools;—On the Upper Silurians of Lesmahago, Lanarkshire;—Alphonse Gages, Report on the Results obtained by the Mechanico-Chemical Examination of Rocks and Minerals;—William Fairbairn, Experiments to determine the Efficiency of Continuous and Self-acting Breaks for Railway Trains;—Professor J. R. Kinahan, Report of Dublin Bay Dredging Committee for 1858–59;—Rev. Baden Powell, Report on Observations of Luminous Meteors for 1858–59;—Professor Owen, Report on a Series of Skulls of various Tribes of Mankind inhabiting Nepal, collected, and presented to the British Museum, by Bryan H. Hodgson, Esq., late Resident in Nepal, &c. &c.;—Messrs. Maskelyne, Hadow, Hardwich, and Llewelyn, Report on the Present State of our Knowledge regarding the Photographic Image;—G. C. Hyndman, Report of the Belfast Dredging Committee for 1859;—James Oldham, Continuation of Report of the Progress of Steam Navigation at Hull;—Charles Atherton, Mercantile Steam Transport Economy as affected by the Consumption of Coals;—Warren de la Rue, Report on the present state of Celestial Photography in England;—Professor Owen, on the Orders of Fossil and Recent Reptilia, and their Distribution in Time;—Balfour Stewart, on some Results of the Magnetic Survey of Scotland in the years 1857 and 1858, undertaken, at the request of the British Association, by the late John Welsh, Esq., F.R.S.;—W. Fairbairn, The Patent Laws: Report of Committee on the Patent Laws;—J. Park Harrison, Lunar Influence on the Temperature of the Air;—Balfour Stewart, an Account of the Construction of the Self-recording Magnetographs at present in operation at the Kew Observatory of the British Association;—Prof. H. J. Stephen Smith, Report on the Theory of Numbers, Part I.;—Report of the Committee on Steamship performance;—Report of the Proceedings of the Balloon Committee of the British Association appointed at the Meeting at Leeds;—Prof. William K. Sullivan, Preliminary Report on the Solubility of Salts at Temperatures above 100° Cent., and on the Mutual Action of Salts in Solution.

Together with the Transactions of the Sections, Prince Albert's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTIETH MEETING, at Oxford, June and July 1860, *Published at 15s.*

CONTENTS:—James Glaisher, Report on Observations of Luminous Meteors, 1859–60;—J. R. Kinahan, Report of Dublin Bay Dredging Committee;—Rev. J. Anderson, Report on the Excavations in Dura Den;—Professor Buckman, Report on the Experimental Plots in the Botanical Garden of the Royal Agricultural College, Cirencester;—Rev. R. Walker, Report of the Committee on Balloon Ascents;—Prof. W. Thomson, Report of Committee appointed to prepare a Self-recording Atmospheric Electrometer for Kew, and Portable Apparatus for observing Atmospheric Electricity;—William Fairbairn, Experiments to determine the Effect of

Vibratory Action and long-continued Changes of Load upon Wrought-iron Girders;—R. P. Greg, Catalogue of Meteorites and Fireballs, from A.D. 2 to A.D. 1860;—Prof. H. J. S. Smith, Report on the Theory of Numbers, Part II.;—Vice-Admiral Moorsom, on the Performance of Steam-vessels, the Functions of the Screw, and the Relations of its Diameter and Pitch to the Form of the Vessel;—Rev. W. V. Harcourt, Report on the Effects of long-continued Heat, illustrative of Geological Phenomena;—Second Report of the Committee on Steamship Performance;—Interim Report on the Gauging of Water by Triangular Notches;—List of the British Marine Invertebrate Fauna.

Together with the Transactions of the Sections, Lord Wrottesley's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-FIRST MEETING, at Manchester, September 1861, *Published at £1.*

CONTENTS:—James Glaisher, Report on Observations of Luminous Meteors;—Dr. E. Smith, Report on the Action of Prison Diet and Discipline on the Bodily Functions of Prisoners, Part I.;—Charles Atherton, on Freight as affected by Differences in the Dynamic Properties of Steamships;—Warren De la Rue, Report on the Progress of Celestial Photography since the Aberdeen Meeting;—B. Stewart, on the Theory of Exchanges, and its recent extension;—Drs. E. Schunck, R. Angus Smith, and H. E. Roscoe, on the Recent Progress and Present Condition of Manufacturing Chemistry in the South Lancashire District;—Dr. J. Hunt, on Ethno-Climatology; or, the Acclimatization of Man;—Prof. J. Thomson, on Experiments on the Gauging of Water by Triangular Notches;—Dr. A. Voelcker, Report on Field Experiments and Laboratory Researches on the Constituents of Manures essential to cultivated Crops;—Prof. H. Hennessy, Provisional Report on the Present State of our Knowledge respecting the Transmission of Sound-signals during Fogs at Sea;—Dr. P. L. Sclater and F. von Hochstetter, Report on the Present State of our Knowledge of the Birds of the Genus *Apteryx* living in New Zealand;—J. G. Jeffreys, Report of the Results of Deep-sea Dredging in Zetland, with a Notice of several Species of Mollusca new to Science or to the British Isles;—Prof. J. Phillips, Contributions to a Report on the Physical Aspect of the Moon;—W. R. Birt, Contribution to a Report on the Physical Aspect of the Moon;—Dr. Collingwood and Mr. Byerley, Preliminary Report of the Dredging Committee of the Mersey and Dee;—Third Report of the Committee on Steamship Performance;—J. G. Jeffreys, Preliminary Report on the Best Mode of preventing the Ravages of *Teredo* and other Animals in our Ships and Harbours;—R. Mallet, Report on the Experiments made at Holyhead to ascertain the Transit-Velocity of Waves, analogous to Earthquake Waves, through the local Rock Formations;—T. Dobson, on the Explosions in British Coal-Mines during the year 1859;—J. Oldham, Continuation of Report on Steam Navigation at Hull;—Professor G. Dickie, Brief Summary of a Report on the Flora of the North of Ireland;—Professor Owen, on the Psychical and Physical Characters of the Mincopies, or Natives of the Andaman Islands, and on the Relations thereby indicated to other Races of Mankind;—Colonel Sykes, Report of the Balloon Committee;—Major-General Sabine, Report on the Repetition of the Magnetic Survey of England;—Interim Report of the Committee for Dredging on the North and East Coasts of Scotland;—W. Fairbairn, on the Resistance of Iron Plates to Statical Pressure and the Force of Impact by Projectiles at High Velocities;—W. Fairbairn, Continuation of Report to determine the effect of Vibratory Action and long-continued Changes of Load upon Wrought-Iron Girders;—Report of the Committee on the Law of Patents;—Prof. H. J. S. Smith, Report on the Theory of Numbers, Part III.

Together with the Transactions of the Sections, Mr. Fairbairn's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-SECOND MEETING, at Cambridge, October 1862, *Published at £1.*

CONTENTS:—James Glaisher, Report on Observations of Luminous Meteors, 1861–62;—G. B. Airy, on the Strains in the Interior of Beams;—Archibald Smith and F. J. Evans, Report on the three Reports of the Liverpool Compass Committee;—Report on Tidal Observations on the Humber;—T. Aston, on Rifled Guns and Projectiles adapted for Attacking Armour-plate Defences;—Extracts, relating to the Observatory at Kew, from a Report presented to the Portuguese Government, by Dr. J. A. de Souza;—H. T. Mennell, Report on the Dredging of the Northumberland Coast and Dogger Bank;—Dr. Cuthbert Collingwood, Report upon the best means of advancing Science through the agency of the Mercantile Marine;—Messrs. Williamson, Wheatstone, Thomson, Miller, Matthiessen, and Jenkin, Provisional Report on Standards of Electrical Resistance;—Preliminary Report of the Committee for investigating the Chemical and Mineralogical Composition of the Granites of Do-

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Together with the Transactions of the Sections, the Rev. Prof. R. Willis's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-THIRD MEETING, at Newcastle-upon-Tyne, August and September 1863, *Published at £1 5s.*

CONTENTS:—Report of the Committee on the Application of Gun-cotton to Warlike Purposes;—A. Matthiessen, Report on the Chemical Nature of Alloys;—Report of the Committee on the Chemical and Mineralogical Constitution of the Granites of Donegal, and of the Rocks associated with them;—J. G. Jeffreys, Report of the Committee appointed for Exploring the Coasts of Shetland by means of the Dredge;—G. D. Gibb, Report on the Physiological Effects of the Bromide of Ammonium;—C. K. Aken, on the Transmutation of Spectral Rays, Part I.:—Dr. Robinson, Report of the Committee on Fog Signals;—Report of the Committee on Standards of Electrical Resistance;—E. Smith, Abstract of Report by the Indian Government on the Foods used by the Free and Jail Populations in India;—A. Gages, Synthetical Researches on the Formation of Minerals, &c.;—R. Mallet, Preliminary Report on the Experimental Determination of the Temperatures of Volcanic Foci, and of the Temperature, State of Saturation, and Velocity of the issuing Gases and Vapours;—Report of the Committee on Observations of Luminous Meteors;—Fifth Report of the Committee on Steamship Performance;—G. J. Allman, Report on the Present State of our Knowledge of the Reproductive System in the Hydroida;—J. Glaisher, Account of Five Balloon Ascents made in 1863;—P. P. Carpenter, Supplementary Report on the Present State of our Knowledge with regard to the Mollusca of the West Coast of North America;—Professor Airy, Report on Steam-boiler Explosions;—C. W. Siemens, Observations on the Electrical Resistance and Electrification of some Insulating Materials under Pressures up to 300 Atmospheres;—C. M. Palmer, on the Construction of Iron Ships and the Progress of Iron Shipbuilding on the Tyne, Wear, and Tees;—Messrs. Richardson, Stevenson, and Clapham, on the Chemical Manufactures of the Northern Districts;—Messrs. Sopwith and Richardson, on the Local Manufacture of Lead, Copper, Zinc, Antimony, &c.;—Messrs. Daglish and Forster, on the Magnesian Limestone of Durham;—I. L. Bell, on the Manufacture of Iron in connexion with the Northumberland and Durham Coal-field;—T. Spencer, on the Manufacture of Steel in the Northern District;—H. J. S. Smith, Report on the Theory of Numbers, Part V.

Together with the Transactions of the Sections, Sir William Armstrong's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-FOURTH MEETING, at Bath, September 1864. *Published* at 18*s*.

CONTENTS:—Report of the Committee for Observations of Luminous Meteors;—Report of the Committee on the best means of providing for a Uniformity of Weights and Measures;—T. S. Cobbold, Report of Experiments respecting the Development and Migration of the Entozoa;—B. W. Richardson, Report on the Physiological Action of Nitrite of Amyl;—J. Oldham, Report of the Committee on Tidal Observations;—G. S. Brady, Report on deep-sea Dredging on the Coasts of Northumberland and Durham in 1864;—J. Glaisher, Account of Nine Balloon Ascents made in 1863 and 1864;—J. G. Jeffreys, Further Report on Shetland Dredgings;—Report of the Committee on the Distribution of the Organic Remains of the North Staffordshire Coal-field;—Report of the Committee on Standards of Electrical Resistance;—G. J. Symons, on the Fall of Rain in the British Isles in 1862 and 1863;—W. Fairbairn, Preliminary Investigation of the Mechanical Properties of the proposed Atlantic Cable.

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PROCEEDINGS OF THE THIRTY-FIFTH MEETING, at Birmingham, September 1865, *Published at* £1 5*s.*

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Together with the Transactions of the Sections, Professor Phillips's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-SIXTH MEETING, at Nottingham, August 1866, *Published at* £1 4*s.*

CONTENTS:—Second Report on Kent's Cavern, Devonshire;—A. Matthiessen, Preliminary Report on the Chemical Nature of Cast Iron;—Report on Observations of Luminous Meteors;—W. S. Mitchell, Report on the Alum Bay Leaf-bed;—Report on the Resistance of Water to Floating and Immersed Bodies;—Dr. Norris, Report on Muscular Irritability;—Dr. Richardson, Report on the Physiological Action of certain compounds of Amyl and Ethyl;—H. Woodward, Second Report on the Structure and Classification of the Fossil Crustacea;—Second Report on the "Menevian Group," and the other Formations at St. David's, Pembrokeshire;—J. G. Jeffreys, Report on Dredging among the Hebrides;—Rev. A. M. Norman, Report on the Coasts of the Hebrides, Part II.;—J. Alder, Notices of some Invertebrata, in connexion with Mr. Jeffreys's Report;—G. S. Brady, Report on the *Ostracoda* dredged amongst the Hebrides;—Report on Dredging in the Moray Firth;—Report on the Transmission of Sound-Signals under Water;—Report of the Lunar Committee;—Report of the Rainfall Committee;—Report on the best means of providing for a Uniformity of Weights and Measures, with reference to the Interests of Science;—J. Glaisher, Account of Three Balloon Ascents;—Report on the Extinct Birds of the Mascarene Islands;—Report on the penetration of Iron-clad Ships by Steel Shot;—J. A. Wanklyn, Report on Isomerism among the Alcohols;—Report on Scientific Evidence in Courts of Law;—A. L. Adams, Second Report on Maltese Fossiliferous Caves, &c.

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PROCEEDINGS OF THE THIRTY-SEVENTH MEETING, at Dundee, September 1867, *Published at* £1 6*s.*

CONTENTS:—Report of the Committee for Mapping the Surface of the Moon;—Third Report on Kent's Cavern, Devonshire;—On the present State of the Manufacture of Iron in Great Britain;—Third Report on the Structure and Classification of the Fossil Crustacea;—Report on the Physiological Action of the Methyl Compounds;—Preliminary Report on the Exploration of the Plant-Beds of North Greenland;—Report of the Steamship Performance Committee;—On the Meteorology of Port Louis in the Island of Mauritius;—On the Construction and Works of the Highland Railway;—Experimental Researches on the Me-

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Together with the Transactions of the Sections, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-EIGHTH MEETING, at Norwich, August 1868, *Published at* £1 5*s*.

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Together with the Transactions of the Sections, Prof. Stokes's Address, and Recommendations of the Association and its Committees.

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CONTENTS:—Report on Steam-boiler Explosions;—Report of the Committee on the Hæmatite Iron-ores of Great Britain and Ireland; -Report on the Sedimentary Deposits of the River Onny;—Report on the Chemical Nature of Cast Iron;—Report on the practicability of establishing "A Close Time" for the protection of Indigenous Animals;—Report on Standards of Electrical Resistance;—Sixth Report on Kent's Cavern;—Third Report on Underground Temperature;—Second Report of the Committee appointed to get cut and prepared Sections of Mountain-Limestone Corals;—Second Report on the Stability, Propulsion, and Sea-going Qualities of Ships;—Report on Earthquakes in Scotland;—Report on the Treatment and Utilization of Sewage;—Report on Observations of Luminous Meteors, 1869–70;—Report on Recent Progress in Elliptic and Hyperelliptic Functions;—Report on Tidal Observations;—On a new Steam-power Meter;—Report on the Action of the Methyl and Allied Series;—Report of the Rainfall Committee;—Report on the Heat generated in the Blood in the process of Arterialization;—Report on the best means of providing for Uniformity of Weights and Measures.

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1860. ‡ACLAND, Sir THOMAS DYKE, Bart., M.A., D.C.L., M.P. Sprydoncote, Exeter; and Athenæum Club, London, S.W.
Adair, John. 13 Merrion-square North, Dublin.
*ADAIR, Colonel Sir ROBERT A. SHAFTO, F.R.S. 7 Audley-square, London, W.
1872. §ADAMS, A. LEITH, M.A., M.B., F.R.S., F.G.S., Staff Surgeon-Major. 30 Bloomfield-terrace, Westbourne-terrace, W.; and Junior United Service Club, Charles-street, St. James's, S.W.
*ADAMS, JOHN COUCH, M.A., D.C.L., F.R.S., F.R.A.S., Director of the Observatory and Lowndean Professor of Astronomy and Geometry in the University of Cambridge. The Observatory, Cambridge.

Year of Election.

1871. §Adams, John R. 15 Old Jewry Chambers, London, E.C.
1869. *ADAMS, WILLIAM GRYLLS, M.A., F.R.S., F.G.S., Professor of Natural Philosophy and Astronomy in King's College, London. 9 Notting-hill-square, London, W.
ADDERLEY, The Right Hon. Sir CHARLES BOWYER, M.P. Hams-hall Coleshill, Warwickshire.
Adelaide, Augustus Short, D.D., Bishop of. South Australia.
1860. *Adie, Patrick. Grove Cottage, Barnes, London, S.W.
1865. *Adkins, Henry. The Firs, Edgbaston, Birmingham.
1845. ‡Ainslie, Rev. G., D.D., Master of Pembroke College. Pembroke Lodge, Cambridge.
1864. *Ainsworth, David. The Flosh, Cleator, Whitehaven.
1871. *Ainsworth, John Stirling. The Flosh, Cleator, Whitehaven.
Ainsworth, Peter. Smithills Hall, Bolton.
1842. *Ainsworth, Thomas. The Flosh, Cleator, Whitehaven.
1871. ‡Ainsworth, William M. The Flosh, Cleator, Whitehaven.
1859. ‡AIRLIE, The Right Hon. The Earl of, K.T. Holly Lodge, Campden Hill, London, W.; and Airlie Castle, Forfarshire.
AIRY, Sir GEORGE BIDDELL, K.C.B., M.A., LL.D., D.C.L., Pres.R.S., F.R.A.S., Astronomer Royal. The Royal Observatory, Greenwich.
1871. §Aitken, John. Darrock, Falkirk, N.B.
1855. ‡Aitkin, John, M.D. 21 Blythswood-square, Glasgow.
Akroyd, Edward, M.P. Bankfield, Halifax.
1862. ‡Alcock, Sir Rutherford. The Athenæum Club, Pall Mall, London.
1861. ‡Alcock, Thomas, M.D. Side Brook, Salemoor, Manchester.
1872. *Alcock, Thomas, M.D. Oakfield, Ashton-on-Mersey, Manchester.
*Aldam, William. Frickley Hall, near Doncaster.
ALDERSON, Sir JAMES, M.A., M.D., D.C.L., F.R.S., Consulting Physician to St. Mary's Hospital. 17 Berkeley-square, London, W.
1857. ‡Aldridge, John, M.D. 20 Ranelagh-road, Dublin.
1859. ‡ALEXANDER, Colonel Sir JAMES EDWARD, K.C.L.S., F.R.A.S., F.R.G.S. Westerton, Bridge of Allan, N.B.
1858. ‡ALEXANDER, WILLIAM, M.D. Halifax.
1850. ‡Alexander, Rev. William Lindsay, D.D., F.R.S.E. Pinkieburn, Musselburgh, by Edinburgh.
1869. ‡*Alger, T. L.*
1867. ‡Alison, George L. C. Dundee.
1863. ‡Allan, Miss. Bridge-street, Worcester.
1859. ‡Allan, Alexander. Scottish Central Railway, Perth.
1871. ‡Allan, G., C.E. 17 Leadenhall-street, London, E.C.
Allan, William. 22 Carlton-place, Glasgow.
1871. §Allen, Alfred H., F.C.S. 1 Surrey-street, Sheffield.
1861. ‡Allen, Richard. Didsbury, near Manchester.
Allen, William. 50 Henry-street, Dublin.
1852. *ALLEN, WILLIAM J. C., Secretary to the Royal Belfast Academical Institution. Ulster Bank, Belfast.
1863. ‡Allhusen, C. Elswick Hall, Newcastle-on-Tyne.
*Allis, Thomas, F.L.S. Osbaldwick Hall, near York.
*ALLMAN, GEORGE J., M.D., F.R.S. L. & E., M.R.I.A. 21 Marlborough-road, London, N.W.; and Athenæum Club, London, S.W.
1868. ‡*Allon, Rev. H.*
1844. *Ambler, Henry. Watkinson Hall, near Halifax.
*Amery, John, F.S.A. Manor House, Eckington, Pershore.
1855. ‡Anderson, Andrew. 2 Woodside-crescent, Glasgow.
1850. ‡Anderson, Charles William. Cleadon, South Shields.

Year of Election.

1871. *Anderson, James. Battlefield House, Langside, Glasgow.
1852. ‡Anderson, Sir James. Glasgow.
1850. ‡Anderson, John. 31 St. Bernard's-crescent, Edinburgh.
1859. ‡ANDERSON, PATRICK. 15 King-street, Dundee.
1850. ‡ANDERSON, THOMAS, M.D., Professor of Chemistry in the University of Glasgow.
1870. ‡Anderson, Thomas Darnley. West Dingle, Liverpool.
1853. *Anderson, William (Yr.). 2 Lennox-street, Edinburgh.
*ANDREWS, THOMAS, M.D., F.R.S., M.R.I.A., F.C.S., Vice-President of, and Professor of Chemistry in, Queen's College, Belfast.
1857. ‡Andrews, William. The Hill, Monkstown, Co. Dublin.
1872. §Andrews, William Patrick, F.R.G.S. 29 Bryanston-square, London, W.
1859. ‡Angus, John. Town House, Aberdeen.
*ANSTED, DAVID THOMAS, M.A., F.R.S., F.G.S., F.R.G.S. 8 Duke-street, Adelphi, London, W.C.; and Melton, Suffolk.
Anthony, John, M.D. Caius College, Cambridge.
1868. ‡ANSTIE, FRANCIS E., M.D. 16 Wimpole-street, London, W.
APJOHN, JAMES, M.D., F.R.S., M.R.I.A., Professor of Chemistry, Trinity College, Dublin. South Hill, Blackrock, Co. Dublin.
1863. ‡Appleby, C. J. Emerson-street, Bankside, Southwark, London, S.E.
1870. ‡Archer, Francis, jun. 3 Brunswick-street, Liverpool.
1855. *ARCHER, THOMAS C., F.R.S.E., Director of the Museum of Science and Art. West Newington House, Edinburgh.
1851. ‡ARGYLL, The Duke of, K.T., LL.D., F.R.S. L. & E., F.G.S. Argyll Lodge, Kensington, London; and Inverary, Argyllshire.
1865. ‡Armitage, J. W., M.D. 9 Huntriss-row, Scarborough.
1861. §Armitage, William. 7 Meal-street, Mosley-street, Manchester.
1867. *Armitstead, George, M.P. Errol Park, Errol, by Dundee.
Armstrong, Thomas. Higher Broughton, Manchester.
1857. *ARMSTRONG, Sir WILLIAM GEORGE, C.B., LL.D., D.C.L., F.R.S. 8 Great George-street, London, S.W.; and Elswick Works, Newcastle-upon-Tyne.
1856. ‡Armstrong, William Jones, M.A. Mount Irwin, Tynna, Co. Armagh.
1868. ‡Arnold, Edward., F.C.S. Prince of Wales-road, Norwich.
1871. §Arnot, William, F.C.S. St. Margaret's, Kirkintilloch, N.B.
ARNOTT, NEIL, M.D., F.R.S., F.G.S. 2 Cumberland-terrace, Regent's Park, London, N.W.
1870. §Arnott, Thomas Reid. Bramshill, Harlesden Green, N.W.
1853. *Arthur, Rev. William, M.A. Clapham Common, London, S.W.
1870. *Ash, Dr. Linnington. Holsworthy, North Devon.
1842. *Ashton, Thomas, M.D. 8 Royal Wells-terrace, Cheltenham.
Ashton, Thomas. Ford Bank, Didsbury, Manchester.
1866. ‡Ashwell, Henry. Mount-street, New Basford, Nottingham.
*Ashworth, Edmund. Egerton Hall, Turton, near Bolton.
Ashworth, Henry. Turton, near Bolton.
1861. ‡Aspland, Alfred. Dukinfield, Ashton-under-Lyne.
Aspland, Algernon Sydney. Glamorgan House, Durdham Down, Bristol.
1861. §Asquith, J. R. Infirmary-street, Leeds.
1861. ‡Aston, Thomas. 4 Elm-court, Temple, London, E.C.
1872. §Atchison, Arthur T. Rose-hill, Dorking.
1858. ‡Atherton, Charles. Sandover, Isle of Wight.
1866. ‡Atherton, J. H., F.C.S. Long-row, Nottingham
1865. ‡Atkin, Alfred. Griffin's-hill, Birmingham.
1861. ‡Atkin, Eli. Newton Heath, Manchester.

Year of Election.

1869. *Atkinson, Anthony Owst, M.A., LL.D. Clare House, Hull; and New University Club, St. James's, London, S.W.
1865. *Atkinson, Edmund, F.C.S. 8 Royal Military College-terrace, York Town, Surrey.
1863. *Atkinson, G. Clayton. Wylam Hall, Northumberland.
1858. *Atkinson, John Hastings. 14 East Parade, Leeds.
1842. *Atkinson, Joseph Beavington. 113 Abington-road, Kensington, London, W.
1861. ‡Atkinson, Rev. J. A. Longsight Rectory, near Manchester.
1858. *Atkinson, J. R. W.
Atkinson, William. Ashton Hayes, near Chester.
1863. *Attfield, Dr. J. 17 Bloomsbury-square, London, W.C.
1860. *Austin-Gourlay, Rev. William E. C., M.A. Stoke Abbott Rectory, Beaminster, Dorset.
1865. *Avery, Thomas. Church-road, Edgbaston, Birmingham.
1865. *Avery, William Henry. Norfolk-road, Edgbaston, Birmingham.
1867. ‡Avison. Thomas, F.S.A. Fulwood Park, Liverpool.
1853. *Ayrton, W. S., F.S.A. Cliffden, Saltburn-by-the-Sea.

Babbage, B. Herschel. 1 Dorset-street, Manchester-square, London, W.
*Babington, Charles Cardale, M.A., F.R.S., F.L.S., F.G.S., Professor of Botany in the University of Cambridge. 5 Brookside, Cambridge.
Bache, Rev. Samuel. 44 Frederick-street, Edgbaston, Birmingham.
1867. *Bagg, Stanley Clark. Fairmount Villa, Montreal, Canada.
Backhouse, Edmund. Darlington.
1863. ‡Backhouse, T. W. West Hendon House, Sunderland.
Backhouse, Thomas James. Sunderland.
1870. §Bailey, Dr. F. J. 51 Grove-street, Liverpool.
1865. ‡Bailey, Samuel, F.G.S. The Peck, Walsall.
1855. ‡Bailey, William. Horseley Fields Chemical Works, Wolverhampton.
1866. ‡Baillon, Andrew. St. Mary's Gate, Nottingham.
1866. ‡Baillon, L. St. Mary's Gate, Nottingham.
1857. ‡Baily, William Hellier, F.L.S., F.G.S., Acting Palæontologist to the Geological Survey of Ireland. 14 Hume-street; and Apsley Lodge, 92 Rathgar-road, Dublin.
*Bain, Richard. Manor Hall, Forest Hill, London, S.E.
1865. ‡Bain, Rev. W. J. Wellingborough.
*Bainbridge, Robert Walton. Middleton House, Middleton-in-Teesdale, by Darlington.
*Baines, Edward, M.P. Belgrave-mansions, Grosvenor-gardens, London, S.W.; and St. Ann's-hill, Burley, Leeds.
1858. ‡Baines, Frederick. Burley, near Leeds.
1865. §Baines, Thomas, F.R.G.S. 35 Austen-street, King's Lynn, Norfolk.
1858. ‡Baines, T. Blackburn. 'Mercury' Office, Leeds.
1866. §Baker, Francis B. Arboretum-street, Nottingham.
1858. *Baker, Henry Granville. Bellevue, Horsforth, near Leeds.
1865. ‡Baker, James P. Wolverhampton.
1861. *Baker, John. Gatley-hill, Cheadle, Cheshire.
1865. ‡Baker, Robert L. Barham House, Leamington.
1849. *Baker, William. 63 Gloucester-place, Hyde Park, London, W.
1863. §Baker, William. 6 Taptonville, Sheffield.
1860. §Balding, James, M.R.C.S. Barkway, Royston, Hertfordshire.
1851. **Baldwin, The Hon. Robert. Spadina, Co. York, Upper Canada.*

Year of Election.

1869. *Atkinson, Anthony Owst, M.A., LL.D. Clare House, Hull; and New University Club, St. James's, London, S.W.
1865. *Atkinson, Edmund, F.C.S. 8 Royal Military College-terrace, York Town, Surrey.
1863. *Atkinson, G. Clayton. Wylam Hall, Northumberland.
1858. *Atkinson, John Hastings. 14 East Parade, Leeds.
1842. *Atkinson, Joseph Beavington. 113 Abington-road, Kensington, London, W.
1861. ‡Atkinson, Rev. J. A. Longsight Rectory, near Manchester.
1858. *Atkinson, J. R. W.
Atkinson, William. Ashton Hayes, near Chester.
1863. *Attfield, Dr. J. 17 Bloomsbury-square, London, W.C.
1860. *Austin-Gourlay, Rev. William E. C., M.A. Stoke Abbott Rectory, Beaminster, Dorset.
1865. *Avery, Thomas. Church-road, Edgbaston, Birmingham.
1865. *Avery, William Henry. Norfolk-road, Edgbaston, Birmingham.
1867. ‡Avison. Thomas, F.S.A. Fulwood Park, Liverpool.
1853. *Ayrton, W. S., F.S.A. Cliffden, Saltburn-by-the-Sea.

Babbage, B. Herschel. 1 Dorset-street, Manchester-square, London, W.
*Babington, Charles Cardale, M.A., F.R.S., F.L.S., F.G.S., Professor of Botany in the University of Cambridge. 5 Brookside, Cambridge.
Bache, Rev. Samuel. 44 Frederick-street, Edgbaston, Birmingham.
1867. *Bagg, Stanley Clark. Fairmount Villa, Montreal, Canada.
Backhouse, Edmund. Darlington.
1863. ‡Backhouse, T. W. West Hendon House, Sunderland.
Backhouse, Thomas James. Sunderland.
1870. §Bailey, Dr. F. J. 51 Grove-street, Liverpool.
1865. ‡Bailey, Samuel, F.G.S. The Peck, Walsall.
1855. ‡Bailey, William. Horseley Fields Chemical Works, Wolverhampton.
1866. ‡Baillon, Andrew. St. Mary's Gate, Nottingham.
1866. ‡Baillon, L. St. Mary's Gate, Nottingham.
1857. ‡Baily, William Hellier, F.L.S., F.G.S., Acting Palæontologist to the Geological Survey of Ireland. 14 Hume-street; and Apsley Lodge, 92 Rathgar-road, Dublin.
*Bain, Richard. Manor Hall, Forest Hill, London, S.E.
1865. ‡Bain, Rev. W. J. Wellingborough.
*Bainbridge, Robert Walton. Middleton House, Middleton-in-Teesdale, by Darlington.
*Baines, Edward, M.P. Belgrave-mansions, Grosvenor-gardens, London, S.W.; and St. Ann's-hill, Burley, Leeds.
1858. ‡Baines, Frederick. Burley, near Leeds.
1865. §Baines, Thomas, F.R.G.S. 35 Austen-street, King's Lynn, Norfolk.
1858. ‡Baines, T. Blackburn. 'Mercury' Office, Leeds.
1866. §Baker, Francis B. Arboretum-street, Nottingham.
1858. *Baker, Henry Granville. Bellevue, Horsforth, near Leeds.
1865. ‡Baker, James P. Wolverhampton.
1861. *Baker, John. Gatley-hill, Cheadle, Cheshire.
1865. ‡Baker, Robert L. Barham House, Leamington.
1849. *Baker, William. 63 Gloucester-place, Hyde Park, London, W.
1863. §Baker, William. 6 Taptonville, Sheffield.
1860. §Balding, James, M.R.C.S. Barkway, Royston, Hertfordshire.
1851. **Baldwin, The Hon. Robert. Spadina, Co. York, Upper Canada.*

Year of Election.

1871. ‡Balfour, Francis Maitland. Trinity College, Cambridge.
1871. ‡Balfour, G. W. Whittinghame, Prestonkirk, Scotland.
*BALFOUR, JOHN HUTTON, M.D., M.A., F.R.S. L. & E., F.L.S., Professor of Botany in the University of Edinburgh. 27 Inverleith-row, Edinburgh.
*BALL, JOHN, F.R.S., F.L.S., M.R.I.A. 24 St. George's-road, Eccleston-square, London, S.W.
1866. *BALL, ROBERT STAWELL, M.A., Professor of Applied Mathematics and Mechanics in the Royal College of Science of Ireland. 47 Wellington-place, Upper Leeson-street, Dublin.
1863. ‡Ball, Thomas. Bramcote, Nottingham.
*Ball, William. Bruce-grove, Tottenham, London, N.; and Glen Rothay, near Ambleside, Westmoreland.
1870. ‡Balmain, William H., F.C.S. Spring Cottage, Great St. Helens, Lancashire.
1869. ‡Bamber, Henry K., F.C.S. 5 Westminster-chambers, Victoria-street, Westminster, S.W.
1852. ‡Bangor, Viscount. Castleward, Co. Down, Ireland.
1861. ‡Bannerman, James Alexander. Limefield House, Higher Broughton near Manchester.
1870. ‡BANISTER, Rev. WILLIAM, B.A. St. James's Mount, Liverpool.
1866. ‡Barber, John. Long-row, Nottingham.
1861. *Barbour, George. Kingslee, Farndon, Chester.
1859. ‡Barbour, George F. 11 George Square, Edinburgh.
*Barbour, Robert. Bolesworth Castle, Tattenhall, Chester.
1855. ‡Barclay, Andrew. Kilmarnock, Scotland.
Barclay, Charles, F.S.A., M.R.A.S. Bury-hill, Dorking.
1871. ‡Barclay, George. 17 Coates-crescent, Edinburgh.
Barclay, James. Catrine, Ayrshire.
1852. *Barclay, J. Gurney. 54 Lombard-street, London, E.C.
1860. *Barclay, Robert. Oak Hall, Wanstead, Essex.
1868. *Barclay, W. L. 54 Lombard-street, London, E.C.
1863. *Barford, James Gale, F.C.S. Wellington College, Wokingham, Berkshire.
1860. *Barker, Rev. Arthur Alcock, B.D. East Bridgeford Rectory, Notts.
1857. ‡Barker, John, M.D., Curator of the Royal College of Surgeons of Ireland. Waterloo-road, Dublin.
1865. ‡Barker, Stephen. 30 Frederick-street, Edgbaston, Birmingham.
1870. ‡BARKLY, Sir HENRY, K.C.B., F.R.S. Bath.
Barlow, Lieut.-Col. Maurice (14th Regt. of Foot). 5 Great George-street, Dublin.
Barlow, Peter. 5 Great George-street, Dublin.
1857. ‡BARLOW, PETER WILLIAM, F.R.S., F.G.S. 8 Eliott-place, Blackheath, London, S.E.
1861. *Barnard, Major R. Cary, F.L.S. Bartlow, Leckhampton, Cheltenham.
1868. §Barnes, Richard H. Care of Messrs. Collyer, 4 Bedford-row, London, W.C.
*Barnes, Thomas, M.D., F.R.S.E. Bunker's Hill, Carlisle.
Barnes, Thomas Addison. 40 Chester-street, Wrexham.
*Barnett, Richard, M.R.C.S. Avon-side, Coten End, Warwickshire.
1859. ‡Barr, Major-General, Bombay Army. Culter House, near Aberdeen. (Messrs. Forbes, Forbes & Co., 9 King William-street, London.)
1861. *Barr, William R., F.G.S. Heaton Lodge, Heaton Mersey, near Manchester.

Year of Election.

1872. *Barrett, F. W., F.C.S. Woodlands, Isleworth, Middlesex.
1860. ‡Barrett, T. B. High-street, Welshpool, Montgomery.
1852. ‡Barrington, Edward. Fassaroe Bray, Co. Wicklow.
1866. ‡Barron, William. Elvaston Nurseries, Borrowash, Derby.
1858. ‡BARRY, Rev. A., D.D., D.C.L., Principal of King's College, London, W.C.
1862. *Barry, Charles. 15 Pembridge-square, Bayswater, London, W.
Barstow, Thomas. Garrow-hill, near York.
1858. *Bartholomew, Charles. Castle-hill-house, Ealing, Middlesex, W.
1855. ‡Bartholomew, Hugh. New Gas-works, Glasgow.
1858. *Bartholomew, William Hamond. Albion Villa, Spencer-place, Leeds.
1868. *Barton, Edward (27th Inniskillens). Clonelly, Ireland.
1857. ‡Barton, Folloit W. Clonelly, Co. Fermanagh.
1852. ‡Barton, James. Farndreg, Dundalk.
*Barton, John. Stonehouse, Sallorgan-road, Booterstown, Dublin.
1864. ‡Bartrum, John S. 41 Gay-street, Bath.
1870. §BARUCHSON, ARNOLD. Blundell Sands, near Liverpool.
1858. *Barwick, John Marshall. Albion-place, Leeds; and Glenview, Shipley, near Leeds.
*Bashforth, Rev. Francis, B.D. Minting Vicarage, near Horncastle.
1861. ‡Bass, John H., F.G.S. 287 Camden-road, London, N.
1866. *BASSETT, HENRY. 215 Hampstead-road, London, N.W.
1866. ‡Bassett, Richard. Pelham-street, Nottingham.
1869. ‡Bastard, S. S. Summerland-place, Exeter.
1871. ‡BASTIAN, H. CHARLTON, M.A., M.D., F.R.S., F.L.S., Professor of Pathological Anatomy to University College Hospital. 20 Queen Anne-street, London, W.
1848. ‡BATE, C. SPENCE, F.R.S., F.L.S. 8 Mulgrave-place, Plymouth.
1868. ‡Bateman, Frederick, M.D. Upper St. Giles's-street, Norwich.
BATEMAN, JAMES, M.A., F.R.S., F.L.S., F.H.S. 9 Hyde Park Gate South, London, W.
1842. *BATEMAN, JOHN FREDERIC, C.E., F.R.S., F.G.S. 16 Great George-street, London, S.W.
1864. §BATES, HENRY WALTER, Assist.-Sec. R.G.S. Saville-row, London, W.
1852. ‡Bateson, Sir Robert, Bart. Belvoir Park, Belfast.
1851. ‡BATH AND WELLS, Lord Arthur Hervey, Lord Bishop of.
1863. *Bathurst, Rev. W. H. 11 Bolton-gardens, South Kensington, London, W.
1869. ‡Batten, John Winterbotham. 35 Palace Gardens-terrace, Kensington, London, S.W.
1863. §BAUERMAN, HENRY, F.G.S. 22 Acre-lane, Brixton, London, S.W.
1861. ‡Baxendell, Joseph, F.R.A.S. 108 Stock-street, Manchester.
1867. ‡Baxter, Edward. Hazel Hall, Dundee.
1867. ‡Baxter, John B. Craig Tay House, Dundee.
1870. ‡BAXTER, R. DUDLEY, M.A. 6 Victoria-street, Westminster, S.W., and Hampstead.
1867. ‡Baxter, William Edward, M.P. Ashcliffe, Dundee.
1868. ‡Bayes, William, M.D. 58 Brook-street, London, W.
1851. *Bayley, George. 2 Cowper's-court, Cornhill, London, E.C.
1866. ‡Bayley, Thomas. Lenton, Nottingham.
1854. ‡Baylis, C. O., M.D. 22 Devonshire-road, Claughton, Birkenhead.
Bayly, John. 1 Brunswick-terrace, Plymouth.
1860. *BEALE, LIONEL S., M.D., F.R.S., Professor of Pathological Anatomy in University College. 61 Grosvenor-street, London, W.
1833. *BEAMISH, RICHARD, F.R.S. Woolston Lawn, Woolston, Southampton.

Year of Election.

1861. §Bean, William. Alfreton, Derbyshire.
1872. §Beanes, Edward, F.C.S. Avon House, Dulwich Common, Surrey.
1870. ‡Beard, Rev. Charles. 13 South-hill-road, Toxteth Park, Liverpool.
*Beatson, William. Chemical Works, Rotherham.
1855. *Beaufort, William Morris, F.R.G.S., M.R.A.S. Athenæum Club, Pall Mall, London, S.W.
1861. *Beaumont, Rev. Thomas George. Chelmondiston Rectory, Ipswich.
1871. *Beazley, Capt. George G. India. (Army and Navy Club, Pall Mall, London, S.W.)
1859. *Beck, Joseph, F.R.A.S. 31 Cornhill, London E.C.
1864. §Becker, Miss Lydia E. Whalley Range, Manchester.
1860. ‡BECKLES, SAMUEL H., F.R.S., F.G.S. 9 Grand Parade, St. Leonards-on-Sea.
1866. ‡Beddard, James. Derby-road, Nottingham.
1870. §BEDDOE, JOHN, M.D. Clifton, Bristol.
1846. ‡BEKE, CHARLES T., Ph.D., F.S.A., F.R.G.S. London Institution, Finsbury-circus, London, E.C.
1865. *BELAVENETZ, I., Captain of the Russian Imperial Navy, F.R.I.G.S., M.S.C.M.A., Superintendent of the Compass Observatory, Cronstadt. (Care of Messrs. Baring Brothers, Bishopsgate-street, London, E.C.)
1847. *BELCHER, Vice-Admiral Sir EDWARD, K.C.B., F.R.A.S., F.R.G.S. 13 Dorset-street, Portman-square, London, W.
1871. ‡Bell, Archibald. Cleator, Carnforth.
1871. §Bell, Charles B. 6 Spring Bank, Hull.
Bell, Frederick John. Woodlands, near Maldon, Essex.
1859. ‡Bell, George. Windsor-buildings, Dumbarton.
1860. ‡Bell, Rev. George Charles, M.A. Christ's Hospital, London, E.C.
1855. ‡Bell, Capt. Henry. Chalfont Lodge, Cheltenham.
1862. *BELL, ISAAC LOWTHIAN. The Hall, Washington, Co. Durham.
1871. *Bell, J. Carter, F.C.S. Cheadle, Cheshire.
1853. ‡Bell, John Pearson, M.D. Waverley House, Hull.
1864. ‡Bell, R. Queen's College, Kingston, Canada.
BELL, THOMAS, F.R.S., F.L.S., F.G.S. The Wakes, Selborne, near Alton, Hants.
1863. *Bell, Thomas. The Minories, Jesmond, Newcastle-on-Tyne.
1867. ‡Bell, Thomas. Belmont, Dundee.
1842. Bellhouse, Edward Taylor. Eagle Foundry, Manchester.
1854. ‡Bellhouse, William Dawson. 1 Park-street, Leeds.
Bellingham, Sir Alan. Castle Bellingham, Ireland.
1866. *BELPER, The Right Hon. Lord, M.A., D.C.L., F.R.S., F.G.S. 88 Eaton-square, London, S.W.; and Kingston Hall, Derby.
1864. *Bendyshe, T. 8 Adelphi-terrace, Strand, London, W.C.
1870. ‡BENNETT, ALFRED W., M.A., B.Sc., F.L.S. 6 Park Village East, Regent's Park, London, N.W.
1871. §Bennett, F. J. 12 Hillmarten-road, Camden-road, London, N.
1838. ‡BENNETT, JOHN HUGHES, M.D., F.R.S.E., Professor of Institutes of Medicine in the University of Edinburgh. 1 Glenfinlas-street, Edinburgh.
1870. *Bennett, William. 109 Shaw-street, Liverpool.
1870. *Bennett, William, jun. Oak Hill Park, Old Swan, near Liverpool.
1852. *Bennoch, Francis. 19 Tavistock-square, London, W.C.
1857. ‡Benson, Charles. 11 Fitzwilliam-square West, Dublin.
Benson, Robert, jun. Fairfield, Manchester.
1848. ‡Benson, Starling, F.G.S. Gloucester-place, Swansea.
1870. ‡Benson, W. Alresford, Hants.
1863. ‡Benson, William. Fourstones Court, Newcastle-on-Tyne.

Year of Election.

1848. ‡BENTHAM, GEORGE, F.R.S., Pres. L.S. 25 Wilton-place, Knightsbridge, London, S.W.
1842. Bentley, John. 9 Portland-place, London, W.
1863. §BENTLEY, ROBERT, F.L.S., Professor of Botany in King's College. 91 Alexandra-road, St. John's-wood, London, N.W.
1868. ‡BERKELEY, Rev. M. J., M.A., F.L.S. Sibbertoft, Market Harborough.
1863. ‡Berkley, C. Marley Hill, Gateshead, Durham.
1848. ‡Berrington, Arthur V. D. Woodlands Castle, near Swansea.
1866. ‡Berry, Rev. Arthur George. Monyash Parsonage, Bakewell, Derbyshire.
1870. ‡Berwick, George, M.D. 36 Fawcett-street, Sunderland.
1862. ‡Besant, William Henry, M.A. St. John's College, Cambridge.
1865. *BESSEMER, HENRY. Denmark-hill, Camberwell, London, S.E.
1858. ‡Best, William. Leydon-terrace, Leeds.
Bethune, Admiral, C.B., F.R.G.S. Balfour, Fifeshire.
1859. ‡Beveridge, Robert, M.B. 36 King-street, Aberdeen.
1863. ‡Bewick, Thomas John, F.G.S. Haydon Bridge, Northumberland.
*Bickerdike, Rev. John, M.A. St. Mary's Vicarage, Leeds.
1870. §Bickerton, A. W., F.C.S. The Penn, Portswood, Southampton.
1868. ‡BIDDER, GEORGE PARKER, C.E., F.R.G.S. 24 Great George-street, Westminster, S.W.
1863. ‡Bigger, Benjamin. Gateshead, Durham.
1864. ‡Biggs, Robert. 17 Charles-street, Bath.
1855. ‡Billings, Robert William. 4 St. Mary's-road, Canonbury, London, N.
Bilton, Rev. William, M.A., F.G.S. United University Club, Suffolk-street, London, S.W.; and Chislehurst, Kent.
1842. BINNEY, EDWARD WILLIAM, F.R.S., F.G.S. 40 Cross-street, Manchester.
Birchall, Henry. College House, Bradford.
Birchall, Edwin. Airedale Cliff, Newley, Leeds.
1866. *Birkin, Richard. Ashley Hall, near Nottingham.
*Birks, Rev. Professor Thomas Rawson. Trinity College, Cambridge.
1842. *Birley, Richard. Seedley, Pendleton, Manchester.
1841. *BIRT, WILLIAM RADCLIFF, F.R.A.S. Cynthia-villa, Clarendon-road, Walthamstow, London, N.E.
1871. *BISCHOF, GUSTAV., Professor of Technical Chemistry in the Andersonian University, Glasgow. 234 George-street, Glasgow.
1868. ‡Bishop, John. Thorpe Hamlet, Norwich.
1866. ‡Bishop, Thomas. Bramcote, Nottingham.
1869. ‡Blackall, Thomas. 13 Southernhay, Exeter.
Blackburne, Rev. John, M.A. Yarmouth, Isle of Wight.
Blackburne, Rev. John, jun., M.A. Rectory, Horton, near Chippenham.
1859. ‡Blackie, John Stewart, Professor of Greek. Edinburgh.
1855. *BLACKIE, W. G., Ph.D., F.R.G.S. 17 Stanhope-terrace, Glasgow.
1870. ‡Blackmore, W. Founder's-court, Lothbury, London, E.C.
*BLACKWALL, Rev. JOHN, F.L.S. Hendre House, near Llanrwst, Denbighshire.
1863. ‡Bladen, Charles. Jarrow Iron Company, Newcastle-on-Tyne.
1863. ‡BLAKE, C. CARTER, Ph.D., F.G.S. 170 South Lambeth-road, London, S.W.
1849 *BLAKE, HENRY WOLLASTON, M.A., F.R.S. 8 Devonshire-place, Portland-place, London, W.
1846. *Blake, William. Bridge House, South Petherton, Somerset.
1845. ‡Blakesley, Rev. J. W., B.D. Ware Vicarage, Hertfordshire.
1861. §Blakiston, Matthew. Mobberley, Knutsford.
*Blakiston, Peyton, M.D., F.R.S. Warrior-square, St. Leonard's-on-Sea.

Year of Election.

1868. ‡Blanc, Henry, M.D. 9 Bedford-street, Bedford-square, London, W.C.
*Blomefield, Rev. Leonard, M.A., F.L.S., F.G.S. 19 Belmont, Bath.
1869. ‡Blandford, W. T., F.G.S., Geological Survey of India, Calcutta. (12 Keppel-street, Russell-square, London, W.C.)
Blanshard, William. Redcar.
Blore, Edward, LL.D., F.R.S., F.S.A. 4 Manchester-square, London, W.
1870. ‡Blundell, Thomas Weld. Ince Blundell Hall, Great Crosby, Lancashire.
1859. ‡Blunt, Sir Charles, Bart. Heathfield Park, Sussex.
1859. ‡Blunt, Capt. Richard. Bretlands, Chertsey, Surrey.
Blyth, B. Hall. 135 George-street, Edinburgh.
1850. ‡Blyth, John, M.D., Professor of Chemistry in Queen's College, Cork.
1858. *Blythe, William. Holland Bank, near Accrington.
1870. ‡Boardman, Edward. Queen-street, Norwich.
Boase, Charles W. 25 Drummond-place, Edinburgh.
1845. ‡Bodmer, Rodolphe. Newport, Monmouthshire.
1864. ‡Bogg, J. Louth, Lincolnshire.
1866. §Bogg, Thomas Wemyss. Louth, Lincolnshire.
1859. *Bohn, Henry G., F.L.S., F.R.A.S., F.R.G.S. North End House, Twickenham, London, S.W.
1871. §Bohn, Mrs. North-end House, Twickenham.
1859. ‡Bolster, Rev. Prebendary John A. Cork.
Bolton, R. L. Laurel Mount, Aigburth-road, Liverpool.
1866. ‡Bond, Banks. Low Pavement, Nottingham.
1863. ‡Bond, Francis T., M.D. Hartley Institution, Southampton.
Bond, Henry John Hayes, M.D. Cambridge.
1871. §Bonney, Rev. Thomas George, M.A., F.S.A., F.G.S. St. John's College, Cambridge.
Bonomi, Ignatius. 36 Blandford-square, London, N.W.
Bonomi, Joseph. Soane's Museum, 15 Lincoln's-Inn-fields, London, W.C.
1866. ‡Booker, W. H. Cromwell-terrace, Nottingham.
1861. §Booth, James. Elmfield, Rochdale.
1835. ‡Booth, Rev. James, LL.D., F.R.S., F.R.A.S. The Vicarage, Stone, near Aylesbury.
1861. *Booth, John. Greenbank, Monton, near Manchester.
1861. *Booth, William. Holybank, Cornbrook, Manchester.
1861. *Borchardt, Louis, M.D. Oxford Chambers, Oxford-street, Manchester.
1849. ‡Boreham, William W., F.R.A.S. The Mount, Haverhill, Newmarket.
1863. ‡Borries, Theodore. Lovaine-crescent, Newcastle-on-Tyne.
*Bossey, Francis, M.D. Mayfield, Oxford-road, Red Hill, Surrey.
Bosworth, Rev. Joseph, LL.D., F.R.S., F.S.A., M.R.I.A., Professor of Anglo-Saxon in the University of Oxford. Oxford.
1867. §Botly, William, F.S.A. Salisbury-villa, Hamlet-road, Upper Norwood, London, S.E.
1858. ‡Botterill, John. Burley, near Leeds.
1872. §Bottle, Alexander. Dover.
1868. ‡Bottle, J. T. 28 Nelson-road, Great Yarmouth.
1871. §Bottomley, James Thomson, M.A., F.C.S. The College, Glasgow.
Bottomley, William. Forbreda, Belfast.
1850. ‡Bouch, Thomas, C.E. Oxford-terrace, Edinburgh.
1870. ‡Boult, Swinton. 1 Dale-street, Liverpool.
1866. §Bourne, Stephen. Abberley Lodge, Hudstone-drive, Harrow.
1858. ‡Bousfield, Charles. Roundhay, near Leeds.

Year of Election.

1868. ‡Boulton, W. S. Norwich.
1872. §Bovill, William Edward. 29 James-street, Buckingham-gate, London, S.W.
1870. §Bower, Anthony. Bowerdale, Seaforth, Liverpool.
1867. ‡Bower, Dr. John. Perth.
1846. *BOWERBANK, JAMES SCOTT, LL.D., F.R.S., F.G.S., F.L.S., F.R.A.S. 2 East Ascent, St. Leonard's-on-Sea.
1856. *Bowlby, Miss F. E. 27 Lansdown-crescent, Cheltenham.
1863. ‡Bowman, R. Benson. Newcastle-on-Tyne.
Bowman, William, F.R.S. 5 Clifford-street, London, W.
1869. ‡Bowring, Charles T. Elmsleigh, Princes' Park, Liverpool.
1869. ‡BOWRING, J. C. Larkbeare, Exeter.
1863. ‡Bowron, James. South Stockton-on-Tees.
1863. §Boyd, Edward Fenwick. Moor House, near Durham.
1871. ‡Boyd, Thomas J. 41 Moray-place, Edinburgh.
Boyle, Alexander, M.R.I.A. 35 College Green, Dublin.
1865. ‡BOYLE, Rev. G. D. Soho House, Handsworth, Birmingham.
Brabant, R. H., M.D. Bath.
1869. *Braby, Frederick, F.G.S., F.C.S. Mount Henley, Sydenham Hill, S.E.
1870. §Brace, Edmund. 17 Water-street, Liverpool.
Bracebridge, Charles Holt, F.R.G.S. The Hall, Atherstone, Warwickshire.
1872. §BRADBROOK, E. W., F.S.A., Dir. A.I. 28 Abingdon-street, Westminster, S.W.
1861. *Bradshaw, William. 35 Mosley-street, Manchester.
1842. *BRADY, Sir ANTONIO, F.G.S. Maryland Point, Stratford, Essex.
1857. *Brady, Cheyne, M.R.I.A. Four Courts, Co. Dublin.
Brady, Daniel F., M.D. 5 Gardiner's-row, Dublin.
1863. ‡BRADY, GEORGE S. 22 Fawcett-street, Sunderland.
1862. §BRADY, HENRY BOWMAN, F.L.S., F.G.S. 29 Mosley-street, Newcastle-on-Tyne.
1858. ‡Brae, Andrew Edmund. 29 Park-square, Leeds.
1864. §Braham, Philip. 6 George-street, Bath.
1870. §Braidwood, Dr. Delemere-terrace, Birkenhead.
1864. §Braikenridge, Rev. George Weare, M.A., F.L.S. Clevedon, Somerset.
1865. §BRAMWELL, FREDERICK J., C.E. 37 Great George-street, London, S.W.
1872. §Bramwell, William J. 17 Prince Albert-street, Brighton.
Brancker, Rev. Thomas, M.A. Limington, Somerset.
1867. ‡Brand, William. Milnefield, Dundee.
1861. *Brandreth, Henry. Dickleborough Rectory, Scole, Norfolk.
1852. ‡BRAZIER, JAMES S., F.C.S., Professor of Chemistry in Marischal College and University of Aberdeen.
1857. ‡Brazill, Thomas. 12 Holles-street, Dublin.
1869. *BREADALBANE, The Right Hon. Earl of. Taymouth Castle, N. B.; and Carlton Club, Pall Mall, London, S.W.
1859. ‡Brebner, Alexander C. Audit Office, Somerset House, London, W.C.
1859. *Brebner, James. 6 Albyn-place, Aberdeen.
1867. ‡BRECHIN, The Right Rev. Alexander Penrose Forbes, Lord Bishop of, D.C.L. Castlehill, Dundee.
1868. §Bremridge, Elias. 17 Bloomsbury-square, London, W.C
1869. ‡Brent, Colonel Robert. Woodbury, Exeter.
1860. ‡Brett, G. Salford.
1854. **Brett, Henry Watkins.*
1866. ‡Brettell, Thomas (Mine Agent). Dudley.
1865. §Brewin, William. Cirencester.

Year of Election.

1867. ‡BRIDGMAN, WILLIAM KENCELEY. 69 St. Giles's-street, Norwich.
1870. *Bridson, Joseph R. Belle Isle, Windermere.
1870. §Brierley, Joseph, C.E. Blackburn.
1870. *Brigg, John. Broomfield, Keighley, Yorkshire.
1866. *Briggs, Arthur. Craig Royd, Rawdon, near Leeds.
*BRIGGS, General JOHN, F.R.S., M.R.A.S., F.G.S. 2 Tenterden-street, London, W.
1866. §Briggs, Joseph. Ulverstone, Lancashire.
1863. *BRIGHT, Sir CHARLES TILSTON, C.E., F.G.S., F.R.G.S., F.R.A.S. 69 Lancaster-gate, W.; and 6 Westminster-chambers, Victoria-street, London, S.W.
1870. ‡Bright, H. A., M.A., F.R.G.S. Ashfield, Knotty Ash.
BRIGHT, The Right Hon. John, M.P. Rochdale, Lancashire.
1868. ‡BRINE, Commander LINDESAY. Army and Navy Club, Pall Mall, London, S.W.
1863. ‡*Brivit, Henri.*
1842. Broadbent, Thomas. Marsden-square, Manchester.
1859. *BRODHURST, BERNARD EDWARD. 20 Grosvenor-street, Grosvenor-square, London, W.
1847. ‡BRODIE, Sir BENJAMIN C., Bart., M.A., D.C.L., F.R.S. Brockham Warren, Reigate.
1834. †BRODIE, Rev. JAMES, F.G.S. Monimail, Fifeshire.
1865. ‡BRODIE, Rev. PETER BELLENGER, M.A., F.G.S. Rowington Vicarage, near Warwick.
1853. ‡Bromby, J. H., M.A. The Charter House, Hull.
Bromilow, Henry G. Merton Bank, Southport, Lancashire.
*BROOKE, CHARLES, M.A., F.R.S. 16 Fitzroy-square, London, W.
1855. ‡Brooke, Edward. Marsden House, Stockport, Cheshire.
1864. *Brooke, Rev. J. Ingham. Thornhill Rectory, Dewsbury.
1855. ‡Brooke, Peter William. Marsden House, Stockport, Cheshire.
1863. §Brooks, John Crosse. Wallsend, Newcastle-on-Tyne.
1846. *Brooks, Thomas. Cranshaw Hall, Rawstenstall, Manchester.
Brooks, William. Ordfall-hill, East Retford, Nottinghamshire.
1847. ‡Broome, C. Edward, F.L.S. Elmhurst, Batheaston, near Bath.
1863. *Brough, Lionel H., F.G.S., one of Her Majesty's Inspectors of Coal-Mines. 11 West Mall, Clifton, Bristol.
*BROUN, JOHN ALLAN, F.R.S., Late Astronomer to His Highness the Rajah of Travancore.
1864. ‡Brown, Mrs. 1 Stratton-street, Piccadilly, London, W.
1863. *BROWN, ALEXANDER CRUM, M.D., F.R.S.E., F.C.S., Professor of Chemistry in the University of Edinburgh. 8 Belgrave-crescent, Edinburgh.
1867. ‡Brown, Charles Gage, M.D. 88 Sloane-street, London, S.W.
1855. ‡Brown, Colin. 3 Mansfield-place, Glasgow.
1871. §Brown, David. 17 S. Norton-place, Edinburgh.
1863. *Brown, Rev. Dixon. Unthank Hall, Haltwhistle, Carlisle.
1865. §Brown, Edwin, F.G.S. Burton-upon-Trent.
1858. §Brown, Henry, M.A., LL.D. Daisey Hill, Rawdon, Leeds.
1870. §BROWN, HORACE T. The Bank, Burton-on-Trent.
Brown, Hugh. Broadstone, Ayrshire.
1870. §BROWN, J. CAMPBELL, D.Sc., F.C.S. Royal Infirmary School of Medicine, Liverpool.
1859. ‡Brown, John Crombie, LL.D., F.L.S. Haddington, Scotland.
1863. ‡Brown, John H. 29 Sandhill, Newcastle-on-Tyne.
1863. †Brown, Ralph. Lambton's Bank, Newcastle-on-Tyne.
1871. §BROWN, ROBERT, M.A., Ph.D., F.R.G.S. 4 Gladstone-terrace, Edinburgh.

Year of Election.

1856. *BROWN, SAMUEL, F.S.S., F.R.G.S. The Elms, 42 Larkhall Rise, Clapham, London, S.W.
1868. ‡Brown, Samuel. Grafton House, Swindon, Wilts.
*Brown, Thomas. Lower Hardwick, Chepstow.
*Brown, William. 11 Maiden-terrace, York-road, Upper Holloway, London, N.
1855. ‡Brown, William. 11 Albany-place, Glasgow.
1850. ‡Brown, William, F.R.S.E. 25 Dublin-street, Edinburgh.
1865. ‡Brown, William. 41 *a* New-street, Birmingham.
1863. ‡*Browne, B. Chapman. Tynemouth.*
1866. *Browne, Rev. J. H. Lowdham Vicarage, Nottingham.
1862. *Browne, Robert Clayton, jun., B.A. Browne's Hill, Carlow, Ireland.
1872. §Browne, R. Mackley, F.G.S. Northside, St. John's, Sevenoaks, Kent.
1865. *Browne, William, M.D. The Friary, Lichfield.
1865. §Browning, John, F.R.A.S. 111 Minories, London, E.
1855. §Brownlee, James, Jun. 30 Burnbank-gardens, Glasgow.
Brownlie, Archibald. Glasgow.
1853. ‡Brownlow, William B. Villa-place, Hull.
1852. ‡Bruce, Rev. William. Belfast.
1863. *Brunel, H. M. 18 Duke-street, Westminster, S.W.
1863. ‡Brunel, J. 18 Duke-street, Westminster, S.W.
1871. §Brunnöw, F. Dunsink, Dublin.
1868. ‡Brunton, T. L. 23 Davies-street, London, W.
1859. ‡*Bryant, Arthur C.*
1861. ‡Bryce, James. York Place, Higher Broughton, Manchester.
BRYCE, JAMES, M.A., LL.D., F.R.S.E., F.G.S. High School, Glasgow, and Bowes Hill, Blantyre, by Glasgow.
BRYCE, Rev. R. J., LL.D., Principal of Belfast Academy. Belfast.
1859. ‡Bryson, William Gillespie. Cullen, Aberdeen.
1867. ‡BUCCLEUCH and QUEENSBERRY, His Grace the Duke of, K.G., D.C.L., F.R.S. L. & E., F.L.S. Whitehall-gardens, London, S.W.; and Dalkeith Palace, Edinburgh.
1871. §BUCHAN, ALEXANDER. 72 Northumberland-street, Edinburgh.
1867. ‡Buchan, Thomas. Strawberry Bank, Dundee.
BUCHANAN, ANDREW, M.D. Professor of the Institutes of Medicine in the University of Glasgow. 4 Ethol-place, Glasgow.
Buchanan, Archibald. Catrine, Ayrshire.
Buchanan, D. C. Poulton cum Seacombe, Cheshire.
1871. ‡Buchanan, John Y. 10 Moray-place, Edinburgh.
*Buck, George Watson. Ramsay, Isle of Man.
1864. §BUCKLE, Rev. GEORGE, M.A. Twerton Vicarage, Bath.
1865. *Buckley, Henry. 27 Wheeler's-road, Edgbaston, Birmingham.
1848. *BUCKMAN, JAMES, F.L.S., F.G.S. Bradford Abbas, Sherbourne, Dorsetshire.
1869. ‡Bucknill, J. Hillmorton Hall, near Rugby.
1851. *BUCKTON, GEORGE BOWDLER, F.R.S., F.L.S. Weycombe, Haslemere, Surrey.
1848. *BUDD, JAMES PALMER. Ystalyfera Iron Works, Swansea.
1871. §Bulloch, Matthew. 11 Park-circus, Glasgow.
1845. *BUNBURY, Sir CHARLES JAMES FOX, Bart., F.R.S., F.L.S., F.G.S., F.R.G.S. Barton Hall, Bury St. Edmunds.
1865. ‡Bunce, John Mackray. 'Journal Office,' New-street, Birmingham.
Bunch, Rev. Robert James, B.D. Emanuel Rectory, Loughborough.
1863. §Bunning, T. Wood. 34 Grey-street, Newcastle-on-Tyne.
Bunt, Thomas G. Nugent-place, Bristol.
1842. *Burd, John. 37 Jewin-street, Aldersgate-street, London, E.C.
1869. ‡Burdett-Coutts, Baroness. Stratton-street, Piccadilly, London, W.

Year of Election.

1872. *Burgess, Herbert. 65 High-street, Battle, Sussex.
1857. ‡Burk, J. Lardner, LL.D. 2 North Great George-street, Dublin.
1865. ‡Burke, Luke. 5 Albert-terrace, Acton, London, W.
1869. *Burnell, Arthur Coke. Sidmouth, South Devon.
1859. ‡Burnett, Newell. Belmont-street, Aberdeen.
1872. §Burrows, Sir John Cordy. 62 Old Steine, Brighton.
1860. ‡Burrows, Montague, M.A., Professor of Modern History, Oxford.
1866. *BURTON, FREDERICK M., F.G.S. Highfield, Gainsborough.
1864. ‡Bush, W. 7 Circus, Bath.
Bushell, Christopher. Royal Assurance-buildings, Liverpool.
1855. *BUSK, GEORGE, F.R.S., V.P.L.S., F.G.S., Examiner in Comparative Anatomy in the University of London. 32 Harley-street, Cavendish-square, London, W.
1857. ‡Butt, Isaac, Q.C., M.P. 4 Henrietta-street, Dublin.
1855. *Buttery, Alexander W. Monkland Iron and Steel Company, Cardarroch, near Airdrie.
1872. §Buxton, Charles Louis. Cromer, Norfolk.
1870. ‡Buxton, David, Principal of the Liverpool Deaf and Dumb Institution, Oxford-street, Liverpool.
Buxton, Edward North.
1868. ‡Buxton, S. Gurney. Catton Hall, Norwich.
1872. §Buxton, Sir T. Fowell. Warlies, Waltham Abbey.
1854. ‡BYERLEY, ISAAC, F.L.S. Seacombe, Liverpool.
Byng, William Bateman. Orwell Works House, Ipswich.
1852. ‡Byrne, Very Rev. James. Ergenagh Rectory, Omagh, Armagh.

CABBELL, BENJAMIN BOND, M.A., F.R.S., F.S.A., F.R.G.S. 1 Brick-court, Temple, E.C.; and 52 Portland-place, London, W.
1858. §Cail, John. Stokesley, Yorkshire.
1863. ‡Cail, Richard. Beaconsfield, Gateshead.
1854. §Caine, Nathaniel. 38 Belvedere-road, Princes Park, Liverpool.
1858. *Caine, Rev. William, M.A. Christ Church Rectory, Denton, near Manchester.
1863. ‡Caird, Edward. Finnart, Dumbartonshire.
1861. *Caird, James Key. 8 Magdalene-road, Dundee.
1855. *Caird, James Tennant. Messrs. Caird and Co., Greenock.
1857. ‡Cairnes, Professor.
1868. ‡Caley, A. J. Norwich.
1868. ‡Caley, W. Norwich.
1857. ‡Callan, Rev. N. J., Professor of Natural Philosophy in Maynooth College.
1842. Callender, W. R. The Elms, Didsbury, Manchester.
1853. ‡Calver, E. K., R.N. 21 Norfolk-street, Sunderland.
1857. ‡Cameron, Charles A., M.D. 17 Ely-place, Dublin.
1870. ‡Cameron, John, M.D. 17 Rodney-street, Liverpool.
1859. ‡Campbell, Rev. C. P., Principal of King's College, Aberdeen.
1857. *Campbell, Dugald, F.C.S. 7 Quality-court, Chancery-lane, London, E.C.
Campbell, Sir Hugh P. H., Bart. 10 Hill-street, Berkeley-square, London, W.; and Marchmont House, near Dunse, Berwickshire.
*Campbell, Sir James. 129 Bath-street, Glasgow.
Campbell, John Archibald, M.D., F.R.S.E. Albyn-place, Edinburgh.
1872. §CAMPBELL, Rev. J. R., D.D. Eldon-place, Manningham-lane, Bradford.
1859. ‡Campbell, William. Dunmore, Argyllshire.
1871. ‡Campbell, William Hunter, LL.D. Georgetown, Demerara, British Guiana.

Year of Election.

1862. *CAMPION, Rev. Dr. WILLIAM M. Queen's College, Cambridge.
1853. ‡*Camps, William, M.D.*
1868. *Cann, William. 9 Southernhay, Exeter.
*Carew, William Henry Pole. Antony, Torpoint, Devonport.
CARLISLE, HARVEY GOODWIN, D.D., Lord Bishop of. Carlisle.
1861. ‡Carlton, James. Mosley-street, Manchester.
1867. ‡Carmichael, David (Engineer). Dundee.
1867. §Carmichael, George. 11 Dudhope-terrace, Dundee.
Carmichael, H. 18 Hume-street, Dublin.
Carmichael, John T. C. Messrs. Todd & Co., Cork.
1871. §CARPENTER, CHARLES. Brunswick-square, Brighton.
1871. §Carpenter, Herbert P. 56 Regent's Park-road, London, N.W.
*CARPENTER, PHILIP PEARSALL, B.A., Ph.D. Montreal, Canada.
1854. ‡Carpenter, Rev. R. Lant, B.A. Bridport.
1845. ‡CARPENTER, WILLIAM B., M.D., F.R.S., F.L.S., F.G.S., PRESIDENT, Registrar of the University of London. 56 Regent's Park-road, London, N.W.
1872. §CARPENTER, Dr. WILLIAM LANT. Winfred House, Pembroke-road, Clifton, Bristol.
1842. *Carr, William, M.D., F.L.S., F.R.C.S. Lee Grove, Blackheath, S.E.
1861. *Carrick, Thomas. 5 Clarence-street, Manchester.
1867. §CARRUTHERS, WILLIAM, F.R.S., F.L.S., F.G.S. British Museum, London, W.C.
1861. *Carson, Rev. Joseph, D.D., M.R.I.A. 18 Fitzwilliam-place, Dublin.
1857. ‡CARTE, ALEXANDER, M.D. Royal Dublin Society, Dublin.
1868. §Carteighe, Michael, F.C.S. 172 New Bond-street, London, W.
1870. ‡Carter, Dr. William. 69 Elizabeth-street, Liverpool.
1866. ‡Carter, H. H. The Park, Nottingham.
1855. ‡Carter, Richard, C.E. Long Carr, Barnsley, Yorkshire.
*CARTMELL, Rev. JAMES, D.D., F.G.S., Master of Christ's College. Christ College Lodge, Cambridge.
Cartmell, Joseph, M.D. Carlisle.
1862. ‡Carulla, Facundo, F.A.S.L. Care of Messrs. Daglish and Co., 8 Harrington-street, Liverpool.
1870. §Cartwright, Joshua. 70 King-street, Dukinfield.
1868. ‡Cary, Joseph Henry. Newmarket-road, Norwich.
1866. ‡Casella, L. P., F.R.A.S. South Grove, Highgate, London, N.
1871. §Cash, Joseph. Bird Grove, Coventry.
1842. *Cassels, Rev. Andrew, M.A. Staincliff Hall, near Dewsbury, Yorkshire.
1853. ‡Cator, John B., Commander R.N. 1 Adelaide-street, Hull.
1859. ‡Catto, Robert. 44 King-street, Aberdeen.
1866. ‡CATTON, ALFRED R., M.A., F.R.S.E. Dundonnell House, Dingwall, N.B.
1849. ‡Cawley, Charles Edward. The Heath, Kirsall, Manchester.
1860. §CAYLEY, ARTHUR, LL.D., F.R.S., V.P.R.A.S., Sadlerian Professor of Mathematics in the University of Cambridge. Garden House, Cambridge.
Cayley, Digby. Brompton, near Scarborough.
Cayley, Edward Stillingfleet. Wydale, Malton, Yorkshire.
1871. *Cecil, Lord Sackville. Holwood, Beckenham, Kent.
1870. ‡Chadburn, C. H. Lord-street, Liverpool.
1858. *Chadwick, Charles, M.D. 35 Park-square, Leeds.
1860. ‡CHADWICK, DAVID, M.P. 27 Belsize-park, London, N.W.
1842. CHADWICK, EDWIN, C.B. Richmond, Surrey.
1842. Chadwick, Elias, M.A. Pudleston-court, near Leominster.

Year of Election.

1842. Chadwick, John. Broadfield, Rochdale.
1859. ‡Chadwick, Robert. Highbank, Manchester.
1861. ‡Chadwick, Thomas. Wilmslow Grange, Cheshire.
*CHALLIS, Rev. JAMES, M.A., F.R.S., F.R.A.S., Plumian Professor of Astronomy in the University of Cambridge. 2 Trumpington-street, Cambridge.
1859. ‡Chalmers, John Inglis. Aldbar, Aberdeen.
1865. ‡CHAMBERLAIN, J. H. Christ Church-buildings, Birmingham.
1868. ‡Chamberlin, Robert. Catton, Norwich.
1842. Chambers, George. High Green, Sheffield.
Chambers, John. Ridgefield, Manchester.
1868. ‡Chambers, W. O. Lowestoft, Suffolk.
*Champney, Henry Nelson. 4 New-street, York.
1865. ‡Chance, A. M. Edgbaston, Birmingham.
1865. *Chance, James Simmers. Four Oak's Park, Sutton Coldfield, Birmingham.
1865. §Chance, Robert Lucas. Chad Hill, Edgbaston, Birmingham.
1861. *Chapman, Edward, M.A., F.L.S., F.C.S. Frewen Hall, Oxford.
1861. *Chapman, John. Hill End Mottram, Manchester.
1866. ‡Chapman, William. The Park, Nottingham.
1871. §Chappell, William, F.S.A. Heather Down, Ascot, Berks.
1854. ‡*Chapple, Frederick.*
1871. ‡Charles, T. C., M.D. Queen's College, Belfast.
1836. CHARLESWORTH, EDWARD, F.G.S. 113 Strand, London, W.C.
1863. ‡Charlton, Edward, M.D. 7 Eldon-square, Newcastle-on-Tyne.
1863. ‡*Charlton, F.*
1866. ‡CHARNOCK, RICHARD STEPHEN, Ph.D., F.S.A., F.R.G.S. 8 Gray's Inn-square, London, W.C.
Chatto, W. J. P. Union Club, Trafalgar-square, London, S.W.
1867. *Chatwood, Samuel. 5 Wentworth-place, Bolton.
1864. ‡CHEADLE, W. B., M.A., M.D., F.R.G.S. 6 Hyde Park-place, Cumberland Gate, London, W.
1842. *Cheetham, David. Cran Hill, Bath.
*CHEVALLIER, Rev. TEMPLE, B.D., F.R.A.S., Professor of Mathematics and Astronomy in the University of Durham. The College, Durham.
1872. §CHICHESTER, The Right Hon. the Earl of. Stanmer House, Lewes.
CHICHESTER, Richard Durnford, Lord Bishop of. Chichester.
1865. *CHILD, GILBERT W., M.A., M.D., F.L.S. Elmhurst, Great Missenden, Bucks.
1842. *Chiswell, Thomas. 17 Lincoln-grove, Manchester.
1863. ‡Cholmeley, Rev. C. H. Dinton Rectory, Salisbury.
1859. ‡Christie, John, M.D. 46 School-hill, Aberdeen.
1861. ‡Christie, Professor R. C., M.A. 7 St. James's-square, Manchester.
CHRISTISON, Sir ROBERT, Bart., M.D., D.C.L., F.R.S.E., Professor of Dietetics, Materia Medica, and Pharmacy in the University of Edinburgh. Edinburgh.
1870. ‡CHURCH, A. H., F.C.S., Professor of Chemistry in the Royal Agricultural College, Cirencester.
1860. ‡Church, William Selby, M.A. 1 Harcourt-buildings, Temple, London, E.C.
1857. †Churchill, F., M.D. 15 Stephen's-green, Dublin.
1868. ‡Clabburn, W. H. Thorpe, Norwich.
1863. ‡Clapham, A. 3 Oxford-street, Newcastle-on-Tyne.
1863. ‡Clapham, Henry. 5 Summerhill-grove, Newcastle-on-Tyne.
1855. §CLAPHAM, ROBERT CALVERT. Garsdon House, Garsdon, Newcastle-on-Tyne.

Year of Election.

1858. ‡Clapham, Samuel. 17 Park-place, Leeds.
1869. §Clapp, Frederick. 44 Magdalen-street, Exeter.
1857. ‡Clarendon, Frederick Villiers. 11 Blessington-street, Dublin.
**Clark, Rev. Charles, M.A.*
Clark, Courtney K. Haugh End, Halifax.
1859. ‡Clark, David. Coupar Angus, Fifeshire.
Clark, G. T. Bombay; and Athenæum Club, London, S.W.
1846. *CLARK, HENRY, M.D. 2 Arundel-gardens, Kensington, London, W.
1861. ‡Clark, Latimer. 5 Westminster-chambers, Victoria-street, London, S.W.
1855. ‡Clark, Rev. William, M.A. Barrhead, near Glasgow.
1865. ‡Clarke, Rev. Charles. Charlotte-road, Edgbaston, Birmingham.
Clarke, George. Mosley-street, Manchester.
1872. *CLARKE, HYDE. 32 St. George's-square, Pimlico, London, S.W.
1861. *Clarke, J. H. Lark Hill House, Edgeley, Stockport.
1842. Clarke, Joseph. Waddington Glebe, Lincoln.
1851. ‡CLARKE, JOSHUA, F.L.S. Fairycroft, Saffron Walden.
Clarke, Thomas, M.A. Knedlington Manor, Howden, Yorkshire.
1861. ‡Clay, Charles, M.D. 101 Piccadilly, Manchester.
*Clay, Joseph Travis, F.G.S. Rastrick, near Brighouse, Yorkshire.
1856. *Clay, Colonel William. The Slopes, Wallasea, Cheshire.
1866. ‡Clayden, P. W. 13 Tavistock-square, London, W.C.
1857. *Clayton, David Shaw. Norbury, Stockport, Cheshire.
1850. ‡CLEGHORN, HUGH, M.D., F.L.S., late Conservator of Forests, Madras. Stravithy, St. Andrews, Scotland.
1859. ‡Cleghorn, John. Wick.
1861. §CLELAND, JOHN, M.D., F.R.S., Professor of Anatomy and Physiology in Queen's College, Galway.
1857. ‡Clements, Henry. Dromin, Listowel, Ireland.
‡Clerk, Rev. D. M. Deverill, Warminster, Wiltshire.
CLERKE, Rev. C. C., D.D., Archdeacon of Oxford and Canon of Christ Church, Oxford. Milton Rectory, Abingdon, Berkshire.
1852. ‡Clibborn, Edward. Royal Irish Academy, Dublin.
1869. §CLIFFORD, WILLIAM KINGDON, M.A., Professor of Applied Mathematics and Mechanics in University College. 14 Maryland-road, Harrow-road, London, W.
1865. ‡Clift, John E., C.E. Redditch, Bromsgrove, near Birmingham.
1861. *CLIFTON, R. BELLAMY, M.A., F.R.S., F.R.A.S., Professor of Experimental Philosophy in the University of Oxford. Portland Lodge, Park Town, Oxford.
Clonbrock, Lord Robert. Clonbrock, Galway.
1854. ‡Close, The Very Rev. Francis, M.A. Carlisle.
1866. §CLOSE, THOMAS, F.S.A. St. James's-street, Nottingham.
Clough, Rev. Alfred B., B.D. Brandeston, Northamptonshire.
1859. ‡Clouston, Rev. Charles. Sandwick, Orkney.
1861. *Clouston, Peter. 1 Park-terrace, Glasgow.
1863. §Clutterbuck, Thomas. Warkworth, Acklington.
1868. ‡Coaks, J. B. Thorpe, Norwich.
1855. *Coats, Sir Peter. Woodside, Paisley.
1855. *Coats, Thomas. Fergeslie House, Paisley.
Cobb, Edward. South Bank, Weston, near Bath.
1851. *COBBOLD, JOHN CHEVALLIER, M.P. Holywells, Ipswich; and Athenæum Club, London, S.W.
1864. ‡COBBOLD, T. SPENCER, M.D., F.R.S., F.L.S., Lecturer on Zoology and Comparative Anatomy at the Middlesex Hospital. 84 Wimpole-street, Cavendish-square, London, W.
1854. ‡Cockey, William. 38 Burnbank-gardens, Glasgow.

Year of Election.

1861. *Coe, Rev. Charles C. Seymour House, Seymour-street, Leicester.
1864. *Cochrane, James Henry. 129 Lower Baggot-street, Dublin.
1865. ‡Coghill, H. Newcastle-under-Lyme.
1853. ‡Colchester, William, F.G.S. Grundesburgh Hall, Ipswich.
1868. ‡Colchester, W. P. Bassingbourn, Royston.
1859. *Cole, Henry Warwick, Q.C. Warwick.
1860. ‡Coleman, J. J., F.C.S. Jeeswood Hall, Mold, North Wales.
1854. *Colfox, William, B.A. Westmead, Bridport, Dorsetshire.
1857. ‡Colles, William, M.D. 21 Stephen's-green, Dublin.
1861. *Collie, Alexander. 12 Kensington Palace-gardens, London, W.
1869. §Collier, W. F. Woodtown, Horrabridge, South Devon.
1861. ‡*Collinge, John.*
1854. ‡COLLINGWOOD, CUTHBERT, M.A., M.B., F.L.S. 4 Grove-terrace, Belvedere-road, Upper Norwood, Surrey, S.E.
1861. *Collingwood, J. Frederick, F.G.S. Anthropological Institute, 4 St. Martin's-place, London, W.C.
1835. *Collins, James Tertius. Churchfield, Edgbaston, Birmingham.
Collis, Stephen Edward. Listowel, Ireland.
1858. *COLMAN, J. J., M.P. Carrow House, Norwich; and 108 Cannon-street, London, E.C.
1870. §Coltart, Robert. Devonshire-road, Prince's Park, Liverpool.
Colthurst, John. Clifton, Bristol.
1869. ‡*Colvill, W. H.*
*COMPTON, The Rev. Lord Alwyn. Castle Ashby, Northamptonshire.
1846. *Compton, Lord William. 145 Piccadilly, London, W.
1852. ‡Connal, Michael. 16 Lynedock-terrace, Glasgow.
1871. *Connor, Charles C. Sea-court, Bangor, Co. Down, Ireland.
1864. *Conwell, Eugene Alfred, M.R.I.A. Trim, Co. Meath, Ireland.
1859. ‡*Cook, E. R.*
1861. **Cook, Henry.*
1863. ‡COOKE, EDWARD WILLIAM, R.A., F.R.S., F.L.S., F.G.S. Glen Andred, Groombridge, Sussex; and Athenæum Club, Pall Mall, London, S.W.
1868. ‡Cooke, Rev. George H. The Parsonage, Thorpe, Norwich.
Cooke, James R., M.A. 73 Blessington-street, Dublin.
Cooke, J. B. Cavendish Road, Birkenhead.
1868. §COOKE, M. C., M.A. 2 Grosvenor-villas, Upper Holloway, London, N.
Cooke, Rev. T. L., M.A. Magdalen College, Oxford.
Cooke, Sir William Fothergill. Telegraph Office, Lothbury, London, E.C.
1859. *Cooke, William Henry, M.A., Q.C., F.S.A. Rainthorpe Hall, Long Stratton.
1865. ‡Cooksey, Joseph. West Bromwich, Birmingham.
1862. *Cookson, Rev. H. W., D.D. St. Peter's College Lodge, Cambridge.
1863. ‡Cookson, N. C. Benwell Tower, Newcastle-on-Tyne.
1869. §Cooling, Edwin. Mile Ash, Derby.
1850. ‡COOPER, Sir HENRY, M.D. 7 Charlotte-street, Hull.
Cooper, James. 58 Pembridge-villas, Bayswater, London, W.
1868. ‡Cooper, W. J. 28 Duke-street, Westminster, S.W.
1846. ‡Cooper, William White. 19 Berkeley-square, London, W.
1871. ‡Copeland, Ralph, Ph.D. Parsonstown, Ireland.
1868. ‡Copeman, Edward, M.D. Upper King-street, Norwich.
1863. ‡Coppin, John. North Shields.
1842. *Corbet, Richard. Bayshill, Cheltenham.
1842. Corbett, Edward. Ravenoak, Cheadle-hulme, Cheshire.

Year of Election.

1855. ‡Corbett, Joseph Henry, M.D., Professor of Anatomy and Physiology, Queen's College, Cork.
1870. *CORFIELD, W. H., M.A., M.B., F.G.S., Professor of Hygiène and Public Health in University College. 10 Bolton-row, Mayfair, London, W.
Cormack, John Rose, M.D., F.R.S.E. 5 Bedford-square, London, W.C.
Cory, Rev. Robert, B.D., F.C.P.S. Stanground, Peterborough.
Cottam, George. 2 Winsley-street, London, W.
1857. ‡Cottam, Samuel. Brazennose-street, Manchester.
1855. ‡Cotterill, Rev. Henry, Bishop of Grahamstown.
1864. §COTTON, General FREDERICK C. Athenæum Club, Pall Mall, London, S.W.
1869. ‡COTTON, WILLIAM. Pennsylvania, Exeter.
*Cotton, Rev. William Charles, M.A. Vicarage, Frodsham, Cheshire.
1865. ‡Courtald, Samuel, F.R.A.S. 76 Lancaster-gate, London; and Gosfield Hall, Essex.
1834. ‡Cowan, Charles. 38 West Register-street, Edinburgh.
Cowan, John. Valleyfield, Pennycuick, Edinburgh.
1863. ‡Cowan, John A. Blaydon Burn, Durham.
1863. ‡Cowan, Joseph, jun. Blaydon, Durham.
1872. *Cowan, Thomas William. Hawthorn House, Horsham.
1873. *Cowans, John. Cranford, Middlesex.
Cowie, Rev. Benjamin Morgan, M.A. 42 Upper Harley-street, Cavendish-square, London, W.
1871. ‡Cowper, C. E. 3 Great George-street, Westminster, S.W.
1860. ‡Cowper, Edward Alfred, M.I.C.E. 6 Great George-street, Westminster, S.W.
1867. *Cox, Edward. Clement Park, Dundee.
1867. *Cox, George Addison. Beechwood, Dundee.
1867. ‡Cox, James. Clement Park Lochee, Dundee.
1870. *Cox, James. 8 Falkner-square, Liverpool.
Cox, Robert. 25 Rutland-street, Edinburgh.
1867. *Cox, Thomas Hunter. 1 Meadow-place, Dundee.
1866. *Cox, William H. 50 Newhall-street, Birmingham.
1867. ‡Cox, William. Foggley, Lochee, by Dundee.
1871. ‡Cox, William J. 2 Vanburgh-place, Leith.
1854. §CRACE-CALVERT, FREDERICK, Ph.D., F.R.S., F.C.S., Honorary Professor of Chemistry to the Manchester Royal Institution. Royal Institution, Manchester.
Craig, J. T. Gibson, F.R.S.E. 24 York-place, Edinburgh.
1859. ‡Craig, S. The Wallands, Lewes, Sussex.
1857. ‡Crampton, Rev. Josiah., M.R.I.A. The Rectory, Florence-court, Co. Fermanagh, Ireland.
1858. ‡Cranage, Edward, Ph.D. The Old Hall, Wellington, Shropshire.
1857. ‡*Crawford, George Arthur, M.A.*
1871. *Crawford, William Caldwell. Eagle Foundry, Port Dundas, Glasgow.
1871. §Crawshaw, Edward. Burnley, Lancashire.
1870. *Crawshay, Mrs. Robert. Cyfartha Castle, Merthyr Tydvil.
1871. ‡Cressley, Herbert. Broomfield, Halifax.
Creyke, The Venerable Archdeacon. Beeford Rectory, Driffield.
1865. ‡Crocker, Edwin, F.C.S. 76 Hungerford Road, Holloway, London, N.
Croft, Rev. John, M.A., F.C.P.S.
1858. ‡Crofts, John. Hillary-place, Leeds.
1859. ‡Croll, A. A. 10 Coleman-street, London, E.C.

Year of Election.

1857. ‡Crolly, Rev. George. Maynooth College, Ireland.
1855. ‡Crompton, Charles, M.A. 22 Hyde Park-square, London, W.
*CROMPTON, Rev. JOSEPH, M.A. Bracondale, Norwich.
1866. ‡Cronin, William. 4 Brunel-terrace, Nottingham.
1870. §Crookes, Joseph. Marlborough House, Brook Green, Hammersmith, London, W.
1865. §CROOKES, WILLIAM, F.R.S., F.C.S. 20 Mornington-road, Regent's Park, London, N.W.
1855. ‡Cropper, Rev. John. Wareham, Dosetshire.
1870. ‡Crosfield, C. J. 5 Alexander-drive, Prince's Park, Liverpool.
1870. *Crosfield, William, jun. 5 Alexander-drive, Prince's Park, Liverpool.
1870. ‡Crosfield, William, sen. Annesley, Aigburth, Liverpool.
1861. ‡Cross, Rev. John Edward, M.A. Appleby Vicarage, near Brigg.
1868. ‡Crosse, Thomas William. St. Giles's-street, Norwich.
1867. §CROSSKEY, Rev. H. W., F.G.S. 28 George-street, Edgbaston, Birmingham.
1853. ‡Crosskill, William, C.E. Beverley, Yorkshire.
1870. *Crossley, Edward. Hermerside, Halifax.
1866. *Crossley, Louis J., F.M.S. Moorside, near Halifax.
1865. ‡Crotch, George Robert. 19 Trumpington-street, Cambridge.
1861. §Crowley, Henry. Smedley New Hall, Cheetham, Manchester.
1863. ‡Crowther, Benjamin. Wakefield.
1863. ‡Cruddas, George. Elswick Engine Works, Newcastle-on-Tyne.
1860. ‡Cruickshank, John. City of Glasgow Bank, Aberdeen.
1859. ‡Cruickshank, Provost. Macduff, Aberdeen.
1859. ‡Crum, James. Busby, Glasgow.
Culley, Robert. Bank of Ireland, Dublin.
1859. ‡Cumming, Sir A. P. Gordon, Bart. Altyre.
1861. *Cunliffe, Edward Thomas. Handforth, Manchester.
1861. *Cunliffe, Peter Gibson. Handforth, Manchester.
1852. ‡Cunningham, John. Macedon, near Belfast.
1869. ‡CUNNINGHAM, Professor ROBERT O., M.D. Queen's College, Belfast.
1855. ‡Cunningham, William A. Manchester and Liverpool District Bank, Manchester.
1850. ‡Cunningham, Rev. William Bruce. Prestonpans, Scotland.
1866. ‡Cunnington, John. 68 Oakley-square, Bedford New Town, London, N.W.
1867. *Cursetjee, Manockjee, F.R.S.A., Judge of Bombay. Villa-Byculla, Bombay.
1857. ‡Curtis, Professor Arthur Hill, LL.D. 6 Trinity College, Dublin.
1866. ‡Cusins, Rev. F. L. 26 Addison-street, Nottingham.
1834. *Cuthbert, John Richmond. 40 Chapel-street, Liverpool.
Cuthbertson, Allan. Glasgow.

1863. ‡Daglish, John. Hetton, Durham.
1854. ‡Daglish, Robert, C.E. Orrell Cottage, near Wigan.
1863. ‡Dale, J. B. South Shields.
1853. ‡Dale, Rev. P. Steele, M.A. Hollingfare, Warrington.
1865. ‡Dale, Rev. R. W. 12 Calthorpe-street, Birmingham.
1867. ‡Dalgleish, Dr. O. Newport, Dundee.
1867. ‡Dalgleish, W. Dundee.
1870. ‡Dallinger, Rev. W. H. Greenfield-road, Stoneycroft, Liverpool.
Dalmahoy, James, F.R.S.E. 9 Forres-street, Edinburgh.
1859. ‡Dalrymple, Charles Elphinstone. West Hall, Aberdeenshire.
1859. ‡Dalrymple, Colonel. Troup, Scotland.
1867. *DALRYMPLE, DONALD, M.D., M.P., F.R.G.S. Thorpe Lodge, Norwich.

Year of
Election.

Dalton, Edward, LL.D., F.S.A. Dunkirk House, Nailsworth.
1859. ‡*Daly, Lieut.-Colonel H. D.*
Dalziel, John, M.D. Holm of Drumlanrig, Thornhill, Dumfriesshire.
1862. ‡Danby, T. W. Downing Collge, Cambridge.
1859. ‡Dancer, J. B., F.R.A.S. Old Manor House, Ardwick, Manchester.
1849. **Danson, Joseph, F.C.S.*
Danson, William. 6 Shaw-street, Liverpool.
1859. ‡Darbishire, Charles James. Rivington, near Chorley, Lancashire.
1861. *DARBISHIRE, ROBERT DUKINFIELD, B.A., F.G.S. 26 George-street, Manchester.
1852. ‡*Darby, Rev. Jonathan L.*
DARWIN, CHARLES R., M.A., F.R.S., F.L.S., F.G.S., Hon. F.R.S.E., and M.R.I.A., Down, near Bromley, Kent.
1848. ‡DaSilva, Johnson. Burntwood, Wandsworth Common, London, S.W.
1872. §Davenport, John T. 64 Marine Parade, Brighton.
Davey, Richard, F.G.S. Redruth, Cornwall.
1870. ‡Davidson, Alexander, M.D. 8 Peel-street, Toxteth Park, Liverpool.
1859. ‡Davidson, Charles. Grove House, Auchmull, Aberdeen.
1871. §Davidson, David. Newbattle, Dalkeith, N.B.
1859. ‡Davidson, Patrick. Inchmarlo, near Aberdeen.
1872. §DAVIDSON, THOMAS, F.R.S., F.G.S. 8 Denmark-terrace, Brighton.
1868. ‡Davie, Rev. W. C. Cringleford, Norwich.
1863. ‡Davies, Griffith. 17 Cloudesley-street, Islington, London, N.
1870. ‡Davies, Edward, F.C.S. Royal Institution, Liverpool.
Davies, John Birt, M.D. The Laurels, Edgbaston, Birmingham.
1842. Davies-Colley, Dr. Thomas. 40 Whitefriars, Chester.
1870. *Davis, A. S. Roundhay Vicarage, Leeds.
1864. §DAVIS, CHARLES E., F.S.A. 55 Pulteney-street, Bath.
Davis, Rev. David, B.A. Lancaster.
1856. *DAVIS, Sir JOHN FRANCIS, Bart., K.C.B., F.R.S., F.R.G.S. Hollywood, Westbury by Bristol.
1859. ‡DAVIS, J. BARNARD, M.D., F.R.S., F.S.A. Shelton, Staffordshire.
1859. *Davis, Richard, F.L.S. 9 St. Helen's-place, London, E.C.
1864. §Davison, Richard. Beverley-road, Great Driffield, Yorkshire.
1857. ‡Davy, Edmund W., M.D. Kimmage Lodge, Roundtown, near Dublin.
1869. ‡Daw, John. Mount Radford, Exeter.
1869. ‡Daw, R. M. Bedford-circus, Exeter.
1854. *Dawbarn, William. Elmswood, Aigburth, Liverpool.
1859. ‡*Dawes, Captain (Adjutant R.A. Highlanders).*
Dawes, John Samuel, F.G.S. Lappel Lodge, Quinton, near Birmingham.
1860. *Dawes, John T., jun. Perry House, Quinton, near Birmingham.
1864. ‡DAWKINS, W. BOYD, M.A., F.R.S., F.G.S. Birchview, Norman-road, Rusholme, Manchester.
1865. ‡Dawson, George, M.A. Shenstone, Lichfield.
*Dawson, Henry. Shu-le-Crow House, Keswick, Cumberland..
1855. ‡DAWSON, JOHN W., M.A., LL.D., F.R.S., Principal of M'Gill College, Montreal, Canada.
Dawson, John. Barley House, Exeter.
1859. *Dawson, Captain William G. Plumstead Common-road, Kent, S.E.
1865. ‡*Day, Edward Charles H.*
1871. ‡Day, St. John Vincent. 166 Buchanan-street, Glasgow.
1870. §Deacon, G. F. Rock Ferry, Liverpool.
1861. ‡Deacon, Henry. Appleton House, near Warrington.
1870. ‡Deacon, Henry Wade. King's College, London, W.C.

Year of Election.

1859. ‡Dean, David. Banchory, Aberdeen.
1861. ‡Dean, Henry. Colne, Lancashire.
1854. §Deane, Henry, F.L.S. Clapham Common, London, S.W.
1870. *Deane, Rev. George, D.Sc., B.A., F.G.S. The Chestnuts, Moseley-road, Birmingham.
1866. ‡Debus, Heinrich, Ph.D., F.R.S., F.C.S. Lecturer on Chemistry at Guy's Hospital, London, S.E.
1854. *De La Rue, Warren, D.C.L., Ph.D., F.R.S., F.C.S., F.R.A.S. Cranford, Middlesex; and Reform Club, London, S.W.
1870. ‡De Meshin, Thomas. 5 Fig-tree-court, Temple, London, E.C.
Denchar, John. Morningside, Edinburgh.
Denison, Sir William Thomas, K.C.B., Col. R.E., F.R.S., F.R.G.S., East Brent, Weston-super-Mare, Somerset.
*Dent, Joseph. Ribston Hall, Wetherby.
Dent, William Yerbury. Royal Arsenal, Woolwich, S.E.
1870. *Denton, J. Bailey. 22 Whitehall-place, London, S.W.
1856. *Derby, The Right Hon. The Earl of, LL.D., F.R.S., F.R.G.S. 23 St. James's-square, London, S.W.; and Knowsley, near Liverpool.
De Saumarez, Rev. Havilland, M.A. St. Peter's Rectory, Northampton.
1870. ‡Desmond, Dr. 44 Irvine-street, Edge Hill, Liverpool.
1868. ‡Dessé, Etheldred, M.B., F.R.C.S. 43 Kensington Gardens-square, Bayswater, London, W.
De Tabley, George, Lord, F.Z.S. Tabley House, Knutsford, Cheshire.
1869. ‡Devon, The Right Hon. The Earl of. Powderham Castle, near Exeter.
*Devonshire, William, Duke of, K.G., M.A., LL.D., F.R.S., F.G.S., F.R.G.S., Chancellor of the University of Cambridge. Devonshire House, Piccadilly, London, W.; and Chatsworth, Derbyshire.
1868. ‡Dewar, James. Chemical Laboratory, The University, Edinburgh.
1872. §Dewick, Rev. E. S. The College, Eastbourne, Sussex.
1858. ‡Dibb, Thomas Townend. Little Woodhouse, Leeds.
1870. ‡*Dickens, Colonel C. H.*
1852. ‡Dickie, George, M.A., M.D., F.L.S., Professor of Botany in the University of Aberdeen.
1864. *Dickinson, F. H., F.G.S. Kingweston, Somerton, Taunton; and 121 St. George's-square, London, S.W.
1863. ‡Dickinson, G. T. Claremont-place, Newcastle-on-Tyne.
1861. *Dickinson, William Leeson. 1 St. James's-street, Manchester.
1867. §Dickson, Alexander, M.D., Professor of Botany in the University of Glasgow. The College, Glasgow.
1868. ‡Dickson, J. Thompson. 33 Harley-street, London, W.
1863. *Dickson, William, F.S.A., Clerk of the Peace for Northumberland. Alnwick, Northumberland.
1862. *Dilke, Sir Charles Wentworth, Bart., M.P. 76 Sloane-street, London, S.W.
1848. ‡Dillwyn, Lewis Llewelyn, M.P., F.L.S., F.G.S. Parkwern, near Swansea.
1872. §Dines, George. Grosvenor-road, London, S.W.
1869. ‡Dingle, Edward. 19 King-street, Tavistock.
1859. *Dingle, Rev. J. Lanchester Vicarage, Durham.
1837. Dircks, Henry, C.E., LL.D., F.C.S. 48 Charing-cross, London, S.W.
1868. ‡Dittmar, W. The University, Edinburgh.
1853. ‡Dixon, Edward, M.Inst.C.E. Wilton House, Southampton.

Year of Election.

1865. ‡Dixon, L. Hooton, Cheshire.
1861. ‡DIXON, W. HEPWORTH, F.S.A., F.R.G.S. 6 St. James's-terrace, London, N.W.
*Dobbin, Leonard, M.R.I.A. 27 Gardiner's-place, Dublin.
1851. ‡Dobbin, Orlando T., LL.D., M.R.I.A. Ballivor, Kells, Co. Meath.
1860. *Dobbs, Archibald Edward, M.A. Richmond-road, Ealing, Middlesex.
1864. *Dobson, William. Oakwood, Bathwick Hill, Bath.
Dockray, Benjamin. Lancaster.
1870. *Dodd, John. 9 Canning-place, Liverpool.
1857. ‡Dodds, Thomas W., C.E. Rotherham.
*Dodsworth, Benjamin. Burton Croft, York.
*Dodsworth, George. Clifton-grove, near York.
Dolphin, John. Delves House, Berry Edge, near Gateshead.
1851. ‡Domvile, William C., F.Z.S. Thorn Hill, Bray, Dublin.
1867. ‡Don, John. The Lodge, Broughty Ferry, by Dundee.
1867. ‡Don, William G. St. Margaret's, Broughty Ferry, by Dundee.
*Donisthorpe, George Edmund. Belvedere, Harrowgate, Yorkshire.
1869. ‡Donisthorpe, G. T. St. David's Hill, Exeter.
1871. ‡DONKIN, ARTHUR SCOTT, M.D., Lecturer on Forensic Medicine at Durham University. Sunderland.
1861. ‡Donnelly, Captain, R.E. South Kensington Museum, London, W.
1857. *DONNELLY, WILLIAM, C.B., Registrar-General for Ireland. 5 Henrietta-street, Dublin.
1857. ‡Donovan, M., M.R.I.A. Clare-street, Dublin.
1867. ‡Dougall, Andrew Maitland, R.N. Scotscraig, Tayport, Fifeshire.
1871. ‡Dougall, John, M.D. 2 Cecil-place, Paisley-road, Glasgow.
1863. *Doughty, C. Montagu. 5 Gloucester-place, Portman-square, London, W.
1855. §DOVE, HECTOR. Rose Cottage, Trinity, near Edinburgh.
1870. ‡Dowie, J. M. Walstones, West Kirby, Liverpool.
Downall, Rev. John. Okehampton, Devon.
1857. ‡DOWNING, S., LL.D., Professor of Civil Engineering in the University of Dublin. Dublin.
1872. *Dowson, Edward, M.D. 117 Park-street, London, W.
1865. *Dowson, E. Theodore. Geldestone, near Beccles, Suffolk.
1869. ‡*Drake, Francis, F.G.S.*
Drennan, William, M.R.I.A. 35 North Cumberland-street, Dublin.
1868. §DRESSER, HENRY E. The Firs, South Norwood, Surrey.
1869. §Drew, Joseph, F.G.S. Weymouth.
1865. ‡Drew, Robert A. 6 Stanley-place, Duke-street, Broughton, Manchester.
1872. *Druce, Frederick. 27 Oriental-place, Brighton.
Drummond, H. Home, F.R.S.E. Blair Drummond, Stirling.
1858. ‡Drummond, James. Greenock.
1859. ‡Drummond, Robert. 17 Stratton-street, London, W.
1866. *Dry, Thomas. 23 Gloucester-road, Regent's Park, London, N.W.
1863. ‡Dryden, James. South Benwell, Northumberland.
1870. §Drysdale. J. J., M.D. 36 A Rodney-street, Liverpool.
1856. *DUCIE, HENRY JOHN REYNOLDS MORETON, Earl of, F.R.S. 16 Portman-square, London, W.; and Tortworth Court, Wotton-under-Edge.
1870. ‡Duckworth, Henry, F.L.S., F.G.S. 5 Cook-street, Liverpool.
1867. *DUFF, MOUNSTUART EPHINSTONE GRANT-, LL.B., M.P. 4 Queen's Gate-gardens, South Kensington, London, W.; and Eden, near Banff, Scotland.
1852. ‡Dufferin, The Rt. Hon. Lord. Highgate, London, N.; and Clandeboye, Belfast.

Year of Election.

1859. *Duncan, Alexander. 7 Princes-gate, London, S.W.
1859. ‡Duncan, Charles. 52 Union-place, Aberdeen.
1866. *Duncan, James. 71 Cromwell-road, South Kensington, London, W.
Duncan, J. F., M.D. 8 Upper Merrion-street, Dublin.
1871. ‡Duncan, James Matthew, M.D. 30 Charlotte-square, Edinburgh.
1867. §DUNCAN, PETER MARTIN, M.D., F.R.S., F.G.S., Professor of Geology in King's College, London. 40 Blessington-road, Lee, S.E.
Dunlop, Alexander. Clober, Milngavie, near Glasgow.
1853. *Dunlop, William Henry. Annan-hill, Kilmarnock, Ayrshire.
1865. §Dunn, David. Annet House, Skelmorlie, by Greenock, N.B.
1862. §DUNN, ROBERT, F.R.C.S. 31 Norfolk-street, Strand, London W.C.
Dunnington-Jefferson, Rev. Joseph, M.A., F.C.P.S. Thicket Hall, York.
1859. ‡Duns, Rev. John, F.R.S.E. 4 North Mansion-House-road, Edinburgh.
1852. ‡Dunville, William. Richmond Lodge, Belfast.
1866. ‡Duprey, Perry. Woodbury Down, Stoke Newington, London, N.
1869. ‡D'Urban, W. S. M., F.L.S. 4 Queen-terrace, Mount Radford, Exeter.
1860. ‡DURHAM, ARTHUR EDWARD, F.R.C.S., F.L.S., Demonstrator of Anatomy, Guy's Hospital. 82 Brook-street, Grosvenor-square, London, W.
1857. ‡Dwyer, Henry L., M.A., M.B. 67 Upper Sackville-street, Dublin.
Dykes, Robert. Kilmorie, Torquay, Devon.
1869. §Dymond, Edward E. Oaklands, Aspley Guise, Woburn.

1868 ‡Eade, Peter, M.D. Upper St. Giles's-street, Norwich.
1861. ‡Eadson, Richard. 13 Hyde-road, Manchester.
1864. ‡Earle, Rev. A. Rectory, Monkton Farleigh, Bath.
Earle, Charles, F.G.S.
*EARNSHAW, Rev. SAMUEL, M.A. Broomfield, Sheffield.
1871. *Easton, Edward. 23 Duke-street, Westminster, S.W.
1863. §Easton, James. Nest House, near Gateshead, Durham
Eaton, Rev. George, M.A. The Pole, Northwich.
1870. ‡Eaton, Richard. North Mymms Park, Hatfield, Herts.
Ebden, Rev. James Collett, M.A., F.R.A.S. Great Stukeley Vicarage, Huntingdonshire.
1867. ‡Eckersley, James. Leith Walk, Edinburgh.
1861. ‡Ecroyd, William Farrer. Spring Cottage, near Burnley.
1858. *Eddison, Francis. Blandford, Dorset.
1870. *Eddison, Dr. John Edwin. 29 Park-square, Leeds.
*Eddy, James Ray, F.G.S. Carleton Grange, Skipton.
Eden, Thomas. Talbot-road, Oxton.
*EDGEWORTH, MICHAEL P., F.L.S., F.R.A.S. Mastrim House, Anerley, London, S.E.
1855. ‡Edmiston, Robert. Elmbank-crescent, Glasgow.
1859. ‡Edmond, James. Cardens Haugh, Aberdeen.
1870. *Edmonds, F. B. 8 York-place, Northam, Southampton.
1867. *Edward, Allan. Farington Hall, Dundee.
1867. §Edward, Charles. Chambers, 8 Bank-street, Dundee.
1867. †Edward, James. Balruddery, Dundee.
Edwards, John. Halifax.
1855. *EDWARDS, Professor J. BAKER, Ph.D., D.C.L. Montreal, Canada.
1867. †Edwards, William. 70 Princes-street, Dundee.
*EGERTON, Sir PHILIP DE MALPAS GREY, Bart., M.P., F.R.S., F.G.S. Oulton Park, Tarporley, Cheshire.
1859. *Eisdale, David A., M.A. 38 Dublin-street, Edinburgh.

Year of
Election.

1855. ‡Elder, David. 19 Paterson-street, Glasgow.
1858. ‡Elder, John. Elm Park, Govan-road, Glasgow.
1868. §Elger, Thomas Gwyn Empy, F.R.A.S. St. Mary, Bedford.
Ellacombe, Rev. H. T., F.S.A. Clyst, St. George, Topsham, Devon.
1863. ‡Ellenberger, J. L. Worksop.
1855. §Elliot, Robert. Wolfelee, Hawick, N.B.
1861. *ELLIOT, Sir WALTER, K.S.I., F.L.S. Wolfelee, Hawick, N.B.
1864. †Elliott, E. B. Washington, United States.
1872. §Elliott, Rev. E. B. 11 Sussex-square, Kemp Town, Brighton.
1862. §Elliott, Frederick Henry, M.A. 449 Strand, London, W.C.
Elliott, John Fogg. Elvet Hill, Durham.
1859. ‡ELLIS, HENRY S., F.R.A.S. Fair Park, Exeter.
1864. *ELLIS, ALEXANDER JOHN, B.A., F.R.S. 25 Argyll-road, Kensington, London, W.
1864. *Ellis, Joseph. Hampton Lodge, Brighton.
1864. §Ellis, J. Walter. High House, Thornwaite, Ripley, Yorkshire.
*Ellis, Rev. Robert, A.M. The Institute, St. Saviour's Gate, York.
1869. ‡Ellis, William Horton. Pennsylvania, Exeter.
Ellman, Rev. E. B. Berwick Rectory, near Lewes, Sussex.
1862. †Elphinstone, H. W., M.A., F.L.S. Cadogan-place, London, S.W.
Eltoft, William. Care of J. Thompson, Esq., 30 New Cannon-street, Manchester.
1863. ‡Embleton, Dennis, M.D. Northumberland-street, Newcastle-on-Tyne.
1863. ‡Emery, Rev. W., B.D. Corpus Christi College, Cambridge.
1858. ‡Empson, Christopher. Brainhope Hall, Leeds.
1866. ‡Enfield, Richard. Low Pavement, Nottingham.
1866. ‡Enfield, William. Low Pavement, Nottingham.
1871. †Engelson, T. 11 Portland-terrace, Regent's Park, London, N.W.
1853. ‡English, Edgar Wilkins. Yorkshire Banking Company, Lowgate, Hull.
1869. §English, J. T. Stratton, Cornwall.
ENNISKILLEN, WILLIAM WILLOUGHBY, Earl of, D.C.L., F.R.S., M.R.I.A., F.G.S. 26 Eaton-place, London, S.W.; and Florence Court, Fermanagh, Ireland.
1869. ‡Ensor, Thomas. St. Leonards, Exeter.
1869. *Enys, John Davis. Canterbury, New Zealand. (Care of J. S. Enys, Esq., Enys, Penryn, Cornwall.)
*Enys, John Samuel, F.G.S. Enys, Penryn, Cornwall.
1844. ‡Erichsen, John Eric, Professor of Clinical Surgery in University College, London. 9 Cavendish-place, London, W.
1864. *Eskrigge, R. A., F.G.S. G 17 Exchange-buildings North, Liverpool.
1862. *ESSON, WILLIAM, M.A., F.R.S., F.C.S., F.R.A.S. Merton College; and 1 Bradmore-road, Oxford.
Estcourt, Rev. W. J. B. Long Newton, Tetbury.
1869. ‡ETHERIDGE, ROBERT, F.R.S.E., F.G.S., Palæontologist to the Geological Survey of Great Britain. Museum of Practical Geology, Jermyn-street; and 19 Halsey-street, Cadogan-place, London, S.W.
1855. *Euing, William. 209 West George-street, Glasgow.
1870. *Evans, Arthur John. Nash Mills, Hemel Hempstead.
1865. *EVANS, Rev. CHARLES, M.A. Solihull Rector, Birmingham.
1872. *Evans, Frederick J., C.E. Clayponds, Brentford, W.
1849. *Evans, George Fabian, M.D. 282 Hagley-road, Birmingham.
1869. *Evans, H. Saville W. 35 Hertford-street, Mayfair, London, W.
1861. *EVANS, JOHN, F.R.S., F.S.A., F.G.S. 65 Old Bailey, London, E.C.; and Nash Mills, Hemel Hempstead.

Year of Election.

1865. ‡Evans, Sebastian, M.A., LL.D. Highgate, near Birmingham.
1866. ‡Evans, Thomas, F.G.S. Belper, Derbyshire.
1865. *Evans, William. Ellerslie, Augustus-road, Edgbaston, Birmingham.
Evanson, R. T., M.D. Holme Hurst, Torquay.
1871. §Eve, H. W. Wellington College, Wokingham, Berkshire.
1868. *Everett, J. D., D.C.L., Professor of Natural Philosophy in Queen's College, Belfast. Rushmere, Malone-road, Belfast.
1863. *Everitt, George Allen, K.L., K.H., F.R.G.S. Knowle Hall, Warwickshire.
1859. *Ewing, Archibald Orr, M.P. Ballikinrain Castle, Killearn, Stirlingshire.
1871. *Exley, John T., M.A. 1 Cotham-road, Bristol.
1846. *Eyre, George Edward, F.G.S., F.R.G.S. 59 Lowndes-square, London, S.W.; and Warren's, near Lyndhurst, Hants.
1866. ‡Eyre, Major-General Sir Vincent, F.R.G.S. Athenæum Club, Pall Mall, London, S.W.
Eyton, Charles. Hendred House, Abingdon.
1849. ‡Eyton, T. C. Eyton, near Wellington, Salop.

1842. Fairbairn, Thomas. Manchester.
*Fairbairn, Sir William, Bart., C.E., LL.D., F.R.S., F.G.S., F.R.G.S. Manchester.
1866. ‡*Fairbank, R. F., M.A.*
1865. ‡Fairley, Thomas. Chapel Allerton, Leeds.
1870. ‡Fairlie, Robert, C.E. Woodlands, Clapham Common, London, S.W.
1864. ‡Falkner, F. H. Lyncombe, Bath.
Fannin, John, M.A. 41 Grafton-street, Dublin.
1859. ‡Farquharson, Robert O. Houghton, Aberdeen.
1861. ‡Farr, William, M.D., D.C.L., F.R.S., Superintendent of the Statistical Department, General Registry Office. Southlands, Bickley, Kent.
1866. *Farrar, Rev. Frederick William, M.A., F.R.S. Marlborough College, Wilts.
1857. ‡Farrelly, Rev. Thomas. Royal College, Maynooth.
1869. *Faulconer, R. S. Fairlawn, Clarence-road, Clapham Park, London.
1869. ‡Faulding, Joseph. 340 Euston-road, London, N.W.
1869. ‡Faulding, W. F. Didsbury College, Manchester.
1859. *Fawcett, Henry, M.P., Professor of Political Economy in the University of Cambridge. 42 Bessborough-gardens, Pimlico, London, S.W.; and 8 Trumpington-street, Cambridge.
1863. ‡Fawcus, George. Alma-place, North Shields.
1833. Fearon, John Peter. Cuckfield, Sussex.
1845. ‡Felkin, William, F.L.S. The Park, Nottingham.
Fell, John B. Spark's Bridge, Ulverston, Lancashire.
1864. §Fellowes, Frank P., F.S.A., F.S.S. 8 The Green, Hampstead, London, N.W.
1852. ‡Fenton, S. Greame. 9 College-square, and Keswick, near Belfast.
1855. ‡Ferguson, James. Gas Coal-works, Lesmahago, Glasgow.
1859. ‡Ferguson, John. Cove, Nigg, Inverness.
1871. §Ferguson, John. The College, Glasgow.
1855. ‡*Ferguson, Peter.*
1867. §Ferguson, Robert M., Ph.D., F.R.S.E. 8 Queen-street, Edinburgh.
1857. ‡Ferguson, Samuel. 20 North Great George-street, Dublin.
1854. ‡Ferguson, William, F.L.S., F.G.S. 2 St. Aiden's-terrace, Birkenhead.
1867. *Fergusson, H. B. 13 Airlie-place, Dundee.
1863. *Fernie, John. Ventnor, Isle of Wight.
1862. ‡Ferrers, Rev. N. M., M.A. Caius College, Cambridge.

Year of Election.

1868. ‡Field, Edward. Norwich.
Field, Edwin W. 36 Lincoln's-Inn-fields, London, W.C.
1869. *Field, Rogers. 5 Canon-row, Westminster, S.W.
Fielding, G. H., M.D. Tunbridge, Kent.
1864. ‡Finch, Frederick George, B.A., F.G.S. 21 Crooms-hill, Greenwich, S.E.
Finch, John. Bridge Work, Chepstow.
Finch, John, jun. Bridge Work, Chepstow.
1859. ‡FINDLAY, ALEXANDER GEORGE, F.R.G.S. 53 Fleet-street, London, E.C.; Dulwich Wood Park, Surrey.
1863. ‡Finney, Samuel. Sheriff-hill Hall, Newcastle-upon-Tyne.
1868. ‡Firth, G. W. W. St. Giles's-street, Norwich.
Firth, Thomas. Northwick.
1863. *Firth, William. Burley Wood, near Leeds.
1851. *FISCHER, WILLIAM L. F., M.A., LL.D., F.R.S., Professor Mathematics in the University of St. Andrews, Scotland.
1858. ‡Fishbourne, Captain E. G., R.N. 6 Welamere-terrace, Paddington, London, W.
1869. ‡FISHER, Rev. OSMOND, M.A., F.G.S. Harlston Rectory, near Cambridge.
1858. ‡Fishwick, Henry. Carr-hill, Rochdale.
1871. *Fison, Frederick W. Greenholme, Burley in Whafldale, near Leeds.
1871. §FITCH, J. G., M.A. 5 Lancaster-terrace, Regent's Park, London, N.W.
1868. ‡Fitch, Robert, F.G.S., F.S.A. Norwich.
1857. ‡Fitzgerald, The Right Hon. Lord Otho, M.P. 13 Dominick-street, Dublin.
1857. ‡Fitzpatrick, Thomas, M.D. 31 Lower Bagot-street, Dublin.
Fitzwilliam, Hon. George Wentworth, M.P., F.R.G.S. 19 Grosvenor-square, London, S.W.; and Wentworth House, Rotherham.
1865. ‡Fleetwood, D. J. 45 George-street, St. Paul's, Birmingham.
Fleetwood, Sir Peter Hesketh, Bart. Rossall Hall, Fleetwood, Lancashire.
1850. ‡Fleming, Professor Alexander, M.D. 20 Temple-row, Birmingham.
Fleming, Christopher, M.D. Merrion-square North, Dublin.
Fleming, John G., M.D. 155 Bath-street, Glasgow.
*FLEMING, WILLIAM, M.D. Rowton Grange, near Chester.
1867. §Fletcher, Alfred E. 21 Overton-street, Liverpool.
1870. §Fletcher, B. Edgington. Norwich.
1853. ‡FLETCHER, ISAAC, F.R.S., F.G.S., F.R.A.S. Tarn Bank, Workington.
1869. §FLETCHER, LAVINGTON E., C.E. 41 Cooperation-street, Manchester.
Fletcher, T. B. E., M.D. 7 Waterloo-street, Birmingham.
1862. ‡FLOWER, WILLIAM HENRY, F.R.S., F.L.S., F.G.S., F.R.C.S., Hunterian Professor of Comparative Anatomy, and Conservator of the Museum of the Royal College of Surgeons. Royal College of Surgeons, Lincoln's-Inn-fields, London, W.C.
1867. ‡Foggie, William. Woodville, Maryfield, Dundee.
1854. *FORBES, DAVID, F.R.S., F.G.S., F.C.S. 11 York-place, Portman-square, London, W.
1855. ‡Forbes, Rev. John. Symington Manse, Biggar, Scotland.
1855. ‡Forbes, Rev. John, D.D. 150 West Regent-street, Glasgow.
Ford, H. R. Morecombe Lodge, Yealand Congers, Lancashire.
1866. ‡Ford, William. Hartsdown Villa, Kensington Park-gardens East, London, W.
*Forrest, William Hutton. The Terrace, Stirling.
1867. ‡Forster, Anthony. Newsham Grange, Winston, Darlington.

Year of Election.

1849. *Forster, Thomas Emerson. 7 Ellison-place, Newcastle-upon-Tyne.
*Forster, William. Ballynure, Clones, Ireland.
1858. ‡Forster, William Edward. Burley, Otley, near Leeds.
1871. ‡Forsyth, William F. Denham Green, Trinity, Edinburgh.
1854. *Fort, Richard. 24 Queen's-gate-gardens, London, W.; and Read Hall, Whalley, Lancashire.
1870. §Forwood, William B. Hopeton House, Seaforth, Liverpool.
1865. ‡Foster, Balthazar W., M.D. 4 Old-square, Birmingham.
1865. *Foster, Clement Le Neve, D.Sc., F.G.S. East Hill, Wandsworth, London, S.W.
1857. *Foster, George C., B.A., F.R.S., F.C.S., Professor of Experimental Physics in University College, London, W.C. 12 Hilldrop-road, London, N.W.
*Foster, Rev. John, M.A. The Oaks Parsonage, Loughborough.
1845. ‡Foster, John N. Sandy Place, Sandy, Bedfordshire.
1859. *Foster, Michael, M.A., M.D., F.L.S. General Secretary. Trinity College, Cambridge.
1859. §Foster, Peter Le Neve, M.A. Society of Arts, Adelphi, London, W.C.
1863. ‡Foster, Robert. 30 Rye-hill, Newcastle-upon-Tyne.
1859. *Foster, S. Lloyd. Old Park Hall, Walsall, Staffordshire.
1842. Fothergill, Benjamin. 10 The Grove, Boltons, West Brompton, London.
1870. ‡Foulger, Edward. 55 Kirkdale-road, Liverpool.
1866. §Fowler, George. Basford Hall, near Nottingham.
1868. ‡Fowler, G. G. Gunton Hall, Lowestoft, Suffolk.
1856. ‡Fowler, Rev. Hugh, M.A. College-gardens, Gloucester.
1870. *Fowler, Robert Nicholas, M.A., M.P., F.R.G.S. 36 Cavendish-square, London, W.
Fox, Alfred. Penjerrick, Falmouth.
1868. ‡Fox, Colonel A. Lane, F.G.S., F.S.A. 10 Upper Phillimore-gardens, Kensington, London, S.W.
1842. *Fox, Charles. Trebah, Falmouth.
*Fox, Rev. Edward, M.A. The Vicarage, Romford, Essex.
*Fox, Joseph Hayland. The Cleve, Wellington, Somerset.
1860. ‡Fox, Joseph John. Church-row, Stoke Newington, London, N.
Fox, Robert Were, F.R.S. Falmouth.
1866. *Francis, G. B. 71 Stoke Newington-road, London, N.
Francis, William, Ph.D., F.L.S., F.G.S., F.R.A.S. Red Lion-court, Fleet-street, London, E.C.; and 1 Matson-villas, Marsh-gate, Richmond, Surrey.
1846. ‡Frankland, Edward, D.C.L., Ph.D., F.R.S., F.C.S., Professor of Chemistry in the Royal School of Mines. 14 Lancaster-gate, London, W.
*Frankland, Rev. Marmaduke Charles. Chowbent, near Manchester.
Franks, Rev. J. C., M.A. Whittlesea, near Peterborough.
1859. ‡Fraser, George B. 3 Airlie-place, Dundee.
Fraser, James. 25 Westland-row, Dublin.
Fraser, James William. 8a Kensington Palace-gardens, London, W.
1865. *Fraser, John, M.A., M.D. Chapel Ash, Wolverhampton.
1871. §Fraser, Thomas R., M.D., F.R.S.E. Grosvenor-place, Edinburgh.
1859. *Frazer, Daniel. 113 Buchanan-street, Glasgow.
1871. ‡Frazer, Evan L. R. Brunswick-terrace, Spring Bank, Hull.
1860. ‡Freeborn, Richard Fernandez. 38 Broad-street, Oxford.
1847. *Freeland, Humphrey William, F.G.S. West-street, Chichester, Sussex.
1871. ‡*Freeman*.

Year of Election.

1865. ‡Freeman, James. 15 Francis-road, Edgbaston, Birmingham.
1869. ‡Frere, Sir Bartle, F.R.G.S. 22 Princes-gardens, London.
Frere, George Edward, F.R.S. Royden Hall, Diss, Norfolk.
1869. ‡Frere, Rev. William Edward. The Rectory, Bilton, near Bristol.
Fripp, George D., M.D. Barnfield Hill, Southampton.
1857. *Frith, Richard Hastings, C.E., M.R.I.A., F.R.G.S.I. 48 Summer-hill, Dublin.
1860. ‡Frodsham, Charles. 26 Upper Bedford-place, Russell-square, London, W.C.
Frost, Charles, F.S.A. Hull.
1847. ‡Frost, William. Wentworth Lodge, Upper Tulse-hill, London, S.W.
1860. *Froude, William, C.E., F.R.S. Chelston Cross, Torquay.
Fry, Francis. Cotham, Bristol.
Fry, Richard. Cotham Lawn, Bristol.
Fry, Robert. Tockington, Gloucestershire.
1863. ‡Fryar, Mark. Eaton Moor Colliery, Newcastle-on-Tyne.
1872. *Fuller, Rev. A. Ichenor, Chichester.
1859. ‡Fuller, Frederick, M.A., Professor of Mathematics in University and King's College, Aberdeen.
1869. ‡Fuller, George, C.E., Professor of Engineering in University College, London. Argyll-road, Kensington, London, W.
1852. ‡Furguson, Professor John C., M.A., M.B. Queen's College, Belfast.
1864. *Furneaux, Rev. Alan. St. Germain's Parsonage, Cornwall.

*Gadesden, Augustus William, F.S.A. Ewell Castle, Surrey.
1857. ‡Gages, Alphonse, M.R.I.A. Museum of Irish Industry, Dublin.
1863. *Gainsford, W. D. Handsworth Grange, near Sheffield.
1850. ‡Gairdner, Professor W. F., M.D. 225 St. Vincent-street, Glasgow.
1861. ‡Galbraith, Andrew. Glasgow.
Galbraith, Rev. J. A., M.R.I.A. Trinity College, Dublin.
1867. ‡Gale, James M. 33 Miller-street, Glasgow.
1863. ‡Gale, Samuel, F.C.S. 338 Oxford-street, London, W.
1861. ‡Galloway, Charles John. Knott Mill Iron Works, Manchester.
1859. ‡*Galloway, James. Calcutta.*
1861. ‡Galloway, John, jun. Knott Mill Iron Works, Manchester.
Galloway, S. H. Linbach, Austria.
1860. *Galton, Captain Douglas, C.B., R.E., F.R.S., F.L.S., F.G.S., F.R.G.S. (General Secretary.) 12 Chester-street, Grosvenor-place, London, S.W.
1860. *Galton, Francis, F.R.S., F.G.S., F.R.G.S. 42 Rutland-gate, Knightsbridge, London, S.W.
1869. †Galton, John C., M.A., F.L.S. 13 Margaret-street, Cavendish-square, London, W.
1870. §Gamble, D. St. Helens, Lancashire.
1870. *Gamble, John G. Albion House, Rottingdean, Brighton.
1868. ‡Gamgee, Arthur, M.D., F.R.S., F.R.S.E. 1 Alva-street, Edinburgh.
1862 §Garner, Robert, F.L.S. Stoke-upon-Trent.
1865. §Garner, Mrs. Robert. Stoke-upon-Trent.
1842. Garnett, Jeremiah. Warren-street, Manchester.
1870. ‡Gaskell, Holbrook. Woolton Wood, Liverpool.
1870. *Gaskell, Holbrook, jun. Mayfield-road, Aigburth, Liverpool.
1847. *Gaskell, Samuel. Windham Club, St. James's-square, London, S.W.
1842. Gaskell, Rev. William, M.A. Plymouth-grove, Manchester.
1846. §Gassiot, John Peter, D.C.L., LL.D., F.R.S., F.C.S. Clapham Common, London, S.W.
1862. *Gatty, Charles Henry, M.A., F.L.S., F.G.S. Felbridge Park, East Grinsted, Sussex.

Year of Election.

1871. ‡Geddes, John. 9 Melville-crescent, Edinburgh.
1859. ‡Geddes, William D., M.A., Professor of Greek, King's College, Old Aberdeen.
1854. ‡Gee, Robert, M.D. 5 Abercromby-square, Liverpool.
1867. §GEIKIE, ARCHIBALD, F.R.S., F.G.S., Director of the Geological Survey of Scotland. Geological Survey Office, Victoria-street, Edinburgh; and Ramsay Lodge, Edinburgh.
1871. §Geikie, James, F.R.S.E. 16 Duncan-terrace, Newington, Edinburgh.
1855. ‡Gemmell, Andrew. 38 Queen-street, Glasgow.
1854. §Gerard, Henry. 8A Rumford-place, Liverpool.
1870. ‡Gerstl, R. University College, London, W.C.
1870. *Gervis, Walter S., M.D. Ashburton, Devon.
1856. *Gething, George Barkley. Springfield, Newport, Monmouthshire.
1863. *GIBB, Sir GEORGE DUNCAN, Bart., M.D., M.A., LL.D., F.G.S. 1 Bryanston-street, London, W.; and Falkland, Fife.
1865. ‡Gibbins, William. Battery Works, Digbeth, Birmingham.
1871. ‡Gibson, Alexander. 19 Albany-street, Edinburgh.
1868. ‡Gibson, C. M. Bethel-street, Norwich.
*Gibson, George Stacey. Saffron Walden, Essex.
1852. ‡Gibson, James. 35 Mountjoy-square, Dublin.
1870. ‡Gibson, R. E. Sankey Mills, Earlestown, near Newton-le-Willows.
1870. ‡Gibson, Thomas. 51 Oxford-street, Liverpool.
1870. ‡Gibson, Thomas, jun. 19 Parkfield-road, Princes Park, Liverpool.
1867. ‡Gibson, W. L., M.D. Tay-street, Dundee.
1842. GILBERT, JOSEPH HENRY, Ph.D., F.R.S., F.C.S. Harpenden, near St. Albans.
1857. ‡Gilbert, J. T., M.R.I.A. Blackrock, Dublin.
1859. *Gilchrist, James, M.D. Crichton Royal Institution, Dumfries.
Gilderdale, Rev. John, M.A. Walthamstow, Essex.
Giles, Rev. William. Netherleigh House, near Chester.
1871. *Gill, David, jun. 26 Silver-street, Aberdeen.
1868. ‡Gill, Joseph. Palermo, Scilly (care of W. H. Gill, Esq., General Post Office, St. Martin's-le-Grand, E.C.).
1864. ‡GILL, THOMAS. 4 Sydney-place, Bath.
1861. *Gilroy, George. Hindley House, Wigan.
1867. ‡Gilroy, Robert. Craigie, by Dundee.
1867. §GINSBURG, Rev. C. D., D.C.L., LL.D. Binfield, Bracknell, Berkshire.
1869. ‡Girdlestone, Rev. Canon E., M.A. Halberton Vicarage, Tiverton.
1850. *Gladstone, George, F.C.S., F.R.G.S. 31 Ventnor-villas, Cliftonville, Brighton.
1849. *GLADSTONE, JOHN HALL, Ph.D., F.R.S., F.C.S. 17 Pembridge-square, Hyde Park, London, W.
1861. *Gladstone, Murray. Broughton House, Manchester.
1852. ‡*Gladstone, Thomas Murray.*
1861. *GLAISHER, JAMES, F.R.S., F.R.A.S. 1 Dartmouth-place, Blackheath, London, S.E.
1871. *GLAISHER, J. W. L., F.R.A.S. Trinity College, Cambridge.
1853. ‡Gleadon, Thomas Ward. Moira-buildings, Hull.
1870. §Glen, David C. 14 Annfield-place, Glasgow.
1859. ‡Glennie, J. S. Stuart. 6 Stone-buildings, Lincoln's Inn, London, W.C.
1867. ‡Gloag, John A. L. 10 Inverleith-place, Edinburgh.
Glover, George. Ranelagh-road, Pimlico, London, S.W.
1870. ‡Glynn, Thomas R. 1 Rodney-street, Liverpool.
1872. §GODDARD, R. Bradford.
1852. ‡Godwin, John. Wood House, Rostrevor, Belfast.

Year of Election.

1846. ‡GODWIN-AUSTEN, ROBERT A. C., B.A., F.R.S., F.G.S. Chilworth Manor, Guildford.

GOLDSMID, Sir FRANCIS HENRY, Bart., M.P. St. John's Lodge, Regent's Park, London, N.W.

1842. *Gouch, Thomas L.*

1852. ‡Goodbody, Jonathan. Clare, King's County, Ireland.

1870. ‡Goodison, George William, C.E. Gateacre, Liverpool.

1842. *GOODMAN, JOHN, M.D. Leicester-street, Southport.

1865. ‡Goodman, J. D. Minories, Birmingham.

1869. ‡Goodman, Neville. Peterhouse, Cambridge.

1870. *Goodwin, Rev. Henry Albert, M.A., F.R.A.S. Westhall Vicarage, Wangford.

1859. ‡*Gordon, H. G.*

1871. §Gordon, Joseph. Poynter's-row, Totteridge, Whetstone, London, N.

1857. ‡Gordon, Samuel, M.D. 11 Hume-street, Dublin.

1865. ‡Gore, George, F.R.S. 50 Islington-row, Edgbaston, Birmingham.

1870. ‡Gossage, William. Winwood, Woolton, Liverpool.

*Gotch, Thomas Henry. Kettering.

1849. ‡Gough, The Hon. Frederick. Perry Hall, Birmingham.

1857. ‡Gough, The Hon. G. S. Rathronan House, Clonmel.

1868. §Gould, Rev. George. Unthank-road, Norwich.

GOULD, JOHN, F.R.S., F.L.S., F.R.G.S., F.Z.S. 26 Charlotte-street, Bedford-square, London, W.C.

1854. ‡Gourlay, Daniel De la C., M.D. Tollington Park, Hornsey-road, London, N.

1867. ‡Gourley, Henry (Engineer). Dundee.

Gowland, James. London-wall, London, E.C.

1861. ‡Grafton, Frederick W. Park-road, Whalley Range, Manchester.

1867. *GRAHAM, CYRIL, F.L.S., F.R.G.S. 9 Cleveland-row, St. James's, London, S.W.

Graham, Lieutenant David. Mecklewood, Stirlingshire.

1852. *Grainger, Rev. John, D.D., Rector of Skerryarea, Rathcavan, Broughshane, near Ballymena, Co. Antrim.

Grainger, Richard.

1871. ‡GRANT, Sir ALEXANDER, Bart., M.A., Principal of the University of Edinburgh. 21 Lansdowne-crescent, Edinburgh.

1870. §GRANT, Colonel J. A., C.B., F.L.S., F.R.G.S. 7 Park-square West, London, N.W.

1859. ‡Grant, Hon. James. Cluny Cottage, Forres.

1855. *GRANT, ROBERT, M.A., LL.D., F.R.S., F.R.A.S., Regius Professor of Astronomy in the University of Glasgow. The Observatory, Glasgow.

1864. ‡Grantham, Richard F. 22 Whitehall-place, London, S.W.

1854. ‡GRANTHAM, RICHARD B., C.E., F.G.S. 22 Whitehall-place, London, S.W.

*Graves, Rev. Richard Hastings, D.D. Brigown Glebe House, Michelstown, Co. Cork.

1870. ‡Gray, C. B. 5 Rumford-place, Liverpool.

1864. *Gray, Rev. Charles. The Vicarage, East Retford.

1865. ‡Gray, Charles. Swan-bank, Bilston.

1857. ‡Gray, Sir John, M.D. Rathgar, Dublin.

**Gray, John.*

*GRAY, JOHN EDWARD, Ph.D., F.R.S., Keeper of the Zoological Collections of the British Museum. British Museum, London, W.C.

1864. ‡Gray, Jonathan. Summerhill House, Bath.

Year of Election.

1870. §Gray, J. Macfarlane. 10 York-grove, Queen's-road, Peckham, London, S.E.
*Gray, William, F.G.S. Minster Yard, York.
1861. *Gray, Lieut.-Colonel William, M.P. 26 Princes-gardens, London, W.
1854. *Grazebrook, Henry, jun. Clent Grove, near Stourbidge, Worcestershire.
1866. §Greaves, Charles Augustus, M.B., LL.B. 32 Friar-gate, Derby.
1869. §Greaves, William. Wellington-circus, Nottingham.
1872. §Greaves, William. Clyde Villa, Preston, Sussex.
1872. *Grece, Clair J. Red Hill, Surrey.
Green, Rev. Henry, M.A. Heathfield, Knutsford, Cheshire.
*Greenaway, Edward. 91 Lansdowne-road, Notting Hill, London, W.
1858. *Greenhalgh, Thomas. Sharples, near Bolton-le-Moors.
1863. ‡Greenwell, G. E. Poynton, Cheshire.
1862. *Greenwood, Henry. 32 Castle-street, and 37 Falkner-square, Liverpool.
1849. †Greenwood, William. Stones, Todmorden.
1861. *Greg, Robert Philips, F.G.S., F.R.A.S. Coles Park, Buntingford, Herts.
1833. Gregg, T. H. 22 Ironmonger-lane, Cheapside, London, E.C.
1860. ‡Gregor, Rev. Walter, M.A. Pitsligo, Rosehearty, Aberdeenshire.
1868. ‡Gregory, Charles Hutton, C.E. 1 Delahay-street, Westminster, S.W.
1861. †Gregson, Samuel Leigh. Aigburth-road, Liverpool.
*Greswell, Rev. Richard, B.D., F.R.S., F.R.G.S. 39 St. Giles's-street, Oxford.
Grey, Captain The Hon. Frederick William. Howick, Northumberland.
1869. †Grey, Sir George, F.R.G.S. Belgrave-mansions, Grosvenor-gardens, London, S.W.
1866. ‡Grey, Rev. William Hewett C. North Sherwood, Nottingham.
1863. ‡Grey, W. S. Norton, Stockton-on-Tees.
1871. *Grierson, Samuel. Medical Superintendent of the District Asylum, Melrose, N.B.
1859. ‡Grierson, Thomas Boyle, M.D. Thornhill, Dumfriesshire.
1870. ‡Grieve, John, M.D. 21 Lynedock-street, Glasgow.
*Griffin, John Joseph, F.C.S. 22 Garrick-street, London, W.C.
Griffith, Rev. C. T., D.D. Elm, near Frome, Somerset.
1859. *Griffith, George, M.A., F.C.S. (Assistant General Secretary.) Harrow.
Griffith, George R. Fitzwilliam-place, Dublin.
1868. ‡Griffith, Rev. John, M.A., D.C.L. Findon Rectory, Worthing, Sussex.
1870. ‡Griffith, N. R. The Coppa, Mold, North Wales.
1870. ‡Griffith, Rev. Professor. Bowden, Cheshire.
*Griffith, Sir Richard John, Bart., LL.D., F.R.S.E., M.R.I.A., F.G.S. 2 Fitzwilliam-place, Dublin.
1847. ‡Griffith, Thomas. Bradford-street, Birmingham.
Griffith, Walter H., M.A.
Griffiths, Rev. John, M.A. 63 St. Giles's, Oxford.
1870. ‡Grimsdale, T. F., M.D. 29 Rodney-street, Liverpool.
1842. Grimshaw, Samuel, M.A. Errwod, Buxton.
1864. ‡Groom-Napier, Charles Ottley, F.G.S. 20 Maryland-road, Harrow-road, London, N.W.
1869. §Grote, Arthur, F.L.S., F.G.S. The Athenæum Club, Pall Mall, London, S.W.

Year of Election.

GROVE, The Hon. Sir WILLIAM ROBERT, M.A., Ph.D., F.R.S. 115 Harley-street, W.
1863. *GROVES, THOMAS B., F.C.S. 80 St. Mary's-street, Weymouth.
1869. ‡GRUBB, HOWARD, F.R.A.S. 40 Leinster-square, Rathmines, Dublin.
1857. ‡GRUBB, THOMAS, F.R.S., M.R.I.A. 141 Leinster-road, Dublin.
1872. §Grüneisen, Charles Lewis, F.R.G.S. 16 Surrey-street, Strand, London, W.C.
Guest, Edwin, LL.D., M.A., F.R.S., F.L.S., F.R.A.S., Master of Caius College, Cambridge. Caius Lodge, Cambridge; and Sandford Park, Oxfordshire.
1867. ‡Guild, John. Bayfield, West Ferry, Dundee.
Guinness, Henry. 17 College-green, Dublin.
1842. Guinness, Richard Seymour. 17 College-green, Dublin.
1856. *GUISE, Sir WILLIAM VERNON, Bart., F.G.S., F.L.S. Elmore Court, near Gloucester.
1862. ‡Gunn, Rev. John, M.A., F.G.S. Irstedd Rectory, Norwich.
1866. ‡GÜNTHER, ALBERT C. L. G., M.D., F.R.S. British Museum, London, W.C.
1868. *Gurney, John. Sprouston Hall, Norwich.
1860. *GURNEY, SAMUEL, M.P., F.L.S., F.R.G.S. 20 Hanover-terrace, Regent's Park, London, N.W.
*Gutch, John James. Holgate Lodge, York.
1859. ‡GUTHRIE, FREDERICK, F.R.S. Professor of Physics in the Royal School of Mines. 24 Stanley-crescent, Notting Hill, London, N.W.
1864. §Guyon, George. South Cliff Cottage, Ventnor, Isle of Wight.
1870. ‡Guyton, Joseph. 23 Cathcart-road, West Brompton, London, S.W.
1857. ‡Gwynne, Rev. John. Tullyaguish, Letterkenny, Strabane, Ireland.

Hackett, Michael. Brooklawn, Chapelizod, Dublin.
1865. §Hackney, William. Walter's-road, Swansea.
1865. ‡Haden, W. H. Cawney Bank Cottage, Dudley.
1866. *Hadden, Frederick J. 3 Park-terrace, Nottingham.
1866. ‡Haddon, Henry. Lenton Field, Nottingham.
Haden, G. N. Trowbridge, Wiltshire.
1842. Hadfield, George. Victoria-park, Manchester.
1870. ‡Hadivan, Isaac. 3 Huskisson-street, Liverpool.
1848. ‡Hadland, William Jenkins. Banbury, Oxfordshire.
1870. ‡Haigh, George. Waterloo, Liverpool.
*Hailstone, Edward, F.S.A. Walton Hall, Wakefield, Yorkshire.
1869. ‡Hake, R. C. Grasmere Lodge, Addison-road, Kensington, London, W.
1870. ‡Halhead, W. B. 7 Parkfield-road, Liverpool.
HALIFAX, The Right Hon. Viscount. 10 Belgrave-square, London, S.W.; and Hickleston Hall, Doncaster.
1872. §Hall, Dr. Alfred. 30 Old Steine, Brighton.
1854. *HALL, HUGH FERGIE. Greenheys, Wallasey, Birkenhead.
1859. ‡Hall, John Frederic. Ellerker House, Richmond, Surrey.
Hall, John Robert. Sutton, Surrey.
1872. *Hall, Captain Marshall. New University Club, St. James's, London, S.W.
*Hall, Thomas B. Australia (care of J. P. Hall, Esq., Crane House, Great Yarmouth).
1866. *HALL, TOWNSHEND M., F.G.S. Pilton, Barnstaple.
1860. §Hall, Walter. 10 Pier-road, Erith.
1868. *HALLETT, WILLIAM HENRY, F.L.S. The Manor House, Kemp Town, Brighton.

Year of Election.

1861. ‡Halliday, James. Whalley Cottage, Whalley Range, Manchester.
1857. ‡Halpin, George, C.E. Rathgar, near Dublin.
Halsall, Edward. 4 Somerset-street, Kingsdown, Bristol.
Halswell, Edmund S., M.A.
1858. *Hambly, Charles Hambly Burbridge, F.G.S. Barrow-on-Soar, near Loughborough.
1866. §HAMILTON, ARCHIBALD, F.G.S. South Barrow, Bromley, Kent.
1857. ‡Hamilton, Charles W. 40 Dominick-street, Dublin.
1865. §Hamilton, Gilbert. Leicester House, Kenilworth-road, Leamington.
HAMILTON, The Very Rev. HENRY PARR, Dean of Salisbury, M.A., F.R.S. L. & E., F.G.S., F.R.A.S. Salisbury.
1869. ‡Hamilton, John, F.G.S. Fyne Court, Bridgewater.
1869. §Hamilton, Roland. Oriental Club, Hanover-square, London, W.
1864. ‡*Hamilton, Rev. S. R., M.A.*
1851. ‡Hammond, C. C. Lower Brook-street, Ipswich.
1871. §Hanbury, Daniel. Clapham Common, London, S.W.
1863. ‡HANCOCK, ALBANY, F.L.S. 4 St. Mary's-terrace, Newcastle-upon-Tyne.
1863. ‡Hancock, John. 4 St. Mary's-terrace, Newcastle-on-Tyne.
1850. ‡Hancock, John. Manor House, Lurgan, Co. Armagh.
1861. ‡Hancock, Walker. 10 Upper Chadwell-street, Pentonville, London.
1857. ‡Hancock, William J. 74 Lower Gardiner-street, Dublin.
1847. ‡HANCOCK, W. NELSON, LL.D. 74 Lower Gardiner-street, Dublin.
1865. ‡Hands, M. Coventry.
Handyside, P. D., M.D., F.R.S.E. 11 Hope-street, Edinburgh.
1867. ‡Hannah, Rev. John, D.C.L. The Vicarage, Brighton.
1859. ‡Hannay, John. Montcoffer House, Aberdeen.
1853. ‡Hansell, Thomas T. 2 Charlotte-street, Sculcoates, Hull.
*HARCOURT, A. G. VERNON, M.A., F.R.S., F.C.S. Christ Church, Oxford.
Harcourt, Rev. C. G. Vernon, M.A. Rothbury, Northumberland.
Harcourt, Egerton V. Vernon, M.A., F.G.S. Whitwell Hall, Yorkshire.
1865. ‡Harding, Charles. Harborne Heath, Birmingham.
1869. ‡Harding, Joseph. Hill's Court, Exeter.
1869. ‡Harding, William D. Islington Lodge, Kings Lynn, Norfolk.
1872. §Hardwicke, Mrs. 192 Piccadilly, London, W.
1864. §Hardwicke, Robert, F.L.S. 192 Piccadilly, London, W.
*HARE, CHARLES JOHN, M.D., Professor of Clinical Medicine in University College, London. 57 Brook-street, Grosvenor-square, London, W.
Harford, Summers. Haverfordwest.
1858. ‡Hargrave, James. Burley, near Leeds.
1853. §HARKNESS, ROBERT, F.R.S. L. & E., F.G.S., Professor of Geology in Queen's College, Cork.
1871. §Harkness, William. Laboratory, Somerset House, London, W.C.
1862. *HARLEY, GEORGE, M.D., F.R.S., Professor of Medical Jurisprudence in University College, London. 25 Harley-street, London, W.
*Harley, John. Ross Hall, near Shrewsbury.
1862. *HARLEY, Rev. ROBERT, F.R.S., F.R.A.S. Mill Hill School, Middlesex; and The Hawthorns, Church End, Finchley, N.
1861. ‡Harman, H. W., C.E. 16 Booth-street, Manchester.
1868. *HARMER, F. W., F.G.S. Heigham Grove, Norwich.
1872. §Harpley, Rev. William, M.A. Clayhange Rectory, Tiverton.
*Harris, Alfred. Oxton Hall, Tadcaster.
*Harris, Alfred, jun. Junefield, Kirkby-Lonsdale, Westmoreland.

Year of Election.

Harris, The Hon. and Right Rev. Charles, Lord Bishop of Gibraltar, F.G.S. (Care of A. Martineau, Esq., 61 Westbourne-terrace, London, W.)
1871. §Harris, George, F.S.A. Iselipps Manor, Northolt, Southall, Middlesex.
*Harris, Henry. Longwood, near Bingley, viâ Leeds.
1863. ‡Harris, T. W. Grange, Middlesborough-on-Tees.
1860. ‡Harrison, Rev. Francis, M.A. Oriel College, Oxford.
1864. §Harrison, George. Barnsley, Yorkshire.
1858. *Harrison, James Park, M.A. Garlands, Ewhurst, Surrey.
1870. ‡Harrison, Reginald. 51 Rodney-street, Liverpool.
1853. ‡Harrison, Robert. 36 George-street, Hull.
1863. ‡Harrison, T. E. Engineers' Office, Central Station, Newcastle-on-Tyne.
1853. *Harrison, William, F.S.A., F.G.S. Samlesbury Hall, near Preston, Lancashire.
1849. ‡Harrowby, The Earl of, K.G., D.C.L., F.R.S., F.R.G.S. 39 Grosvenor-square, London, S.W.; and Sandon Hall, Lichfield.
1859. *Hart, Charles. Harbourne Hall, Birmingham.
1861. *Harter, J. Collier. Chapel Walks, Manchester.
1842. *Harter, William. Hope Hall, Manchester.
1856. ‡Hartland, F. Dixon, F.S.A., F.R.G.S. The Oaklands, near Cheltenham.
Hartley, James. Sunderland.
1871. ‡Hartley, Walter Noel. King's College, London, W.C.
1854. §Hartnup, John, F.R.A.S. Liverpool Observatory, Bidston, Birkenhead.
1850. ‡Harvey, Alexander. 4 South Wellington-place, Glasgow.
1870. ‡Harvey, Enoch. Riversdale-road, Aigburth, Liverpool.
*Harvey, Joseph Charles. Knockrea House, Cork.
Harvey, J. R., M.D. St. Patrick's-place, Cork.
1862. *Harwood, John, jun. Woodside Mills, Bolton-le-moors.
Hastings, Rev. H. S. Martley Rectory, Worcester.
1842. *Hatton, James. Richmond House, Higher Broughton, Manchester.
Haughton, James, M.R.D.S. 34 Eccles-street, Dublin.
1857. †Haughton, Rev. Samuel, M.D., M.A., F.R.S., M.R.I.A., F.G.S., Professor of Geology in the University of Dublin. Trinity College, Dublin.
*Haughton, William. 28 City Quay, Dublin.
Hawkins, John Heywood, M.A., F.R.S., F.G.S. Bignor Park, Petworth, Sussex.
**Hawkins, Thomas, F.G.S.*
1872. *Hawkshaw, Henry Paul. 20 King-street, St. James's, London, W.
*Hawkshaw, John, F.R.S., F.G.S. Hollycombe, Liphook, Petersfield; and 33 Great George-street, London, S.W.
1864. *Hawkshaw, John Clarke, M.A., F.G.S. 25 Cornwall-gardens, South Kensington, W.; and 33 Great George-street, London, S.W.
1868. §Hawksley, Thomas, C.E., F.G.S. 30 Great George-street, London, S.W.
1863. ‡Hawthorn, William. The Cottage, Benwell, Newcastle-upon-Tyne.
1859. ‡Hay, Sir Andrew Leith, Bart. Rannes, Aberdeenshire.
1861. *Hay, Rear-Admiral Sir John C. D., Bart., M.P., F.R.S. 108 St. George's-square, London, S.W.
1858. ‡Hay, Samuel. Albion-place, Leeds.
1867. ‡Hay, William. 21 Magdalen-yard-road, Dundee.
1857. ‡Hayden, Thomas, M.D. 30 Harcourt-street, Dublin.

Year of Election.

1872. §Hayne, W. A. Trinity College, Cambridge.
1869. ‡Hayward, J. High-street, Exeter.
1858. *HAYWARD, ROBERT BALDWIN, M.A. The Park, Harrow-on-the-hill.
1851. §Head, Jeremiah. Middlesborough, Yorkshire.
1869. ‡Head, R. T. The Briars, Alphington, Exeter.
1869. ‡Head, W. R. Bedford-circus, Exeter.
1861. *Heald, James. Parr's Wood, Didsbury, near Manchester.
1863. †Heald, Joseph. 22 Leazes-terrace, Newcastle-on-Tyne.
1872. §Healey, C. E. H. Chadwyck. 8 Albert-mansions, Victoria-street, London, S.W.
1871. §Healey, George. Matson's, Windermere.
1861. *Heape, Benjamin. Northwood, Prestwich, near Manchester.
1865. ‡Hearder, William. Victoria Parade, Torquay.
1866. ‡Heath, Rev. D. J. Esher, Surrey.
1863. ‡Heath, G. Y., M.D. Westgate-street, Newcastle-on-Tyne.
1861. §HEATHFIELD, W. E., F.C.S., F.R.G.S., F.R.S.E. 20 King-street, St. James's, London, S.W.
1865. †Heaton, Harry. Warstone, Birmingham.
1858. *HEATON, JOHN DEAKIN, M.D. Claremont, Leeds.
1865. ‡Heaton, Ralph. Harborne Lodge, near Birmingham.
1833. ‡HEAVISIDE, Rev. CANON J. W. L., M.A. The Close, Norwich.
1863. ‡*Heckels, Richard.*
1855. ‡HECTOR, JAMES, M.D., F.R.S., F.G.S., F.R.G.S., Geological Survey of New Zealand. Wellington, New Zealand.
1867. ‡HEDDLE, M. FOSTER, M.D., Professor of Chemistry in the University of St. Andrew's, N.B.
1869. ‡Hedgeland, Rev. W. J. 21 Mount Radford, Exeter.
1863. ‡Hedley, Thomas. Cox Lodge, near Newcastle-on-Tyne.
1862. †Helm, George F. 58 Trumpington-street, Cambridge.
1857. *Hemans, George William, C.E., M.R.I.A., F.G.S. 1 Westminster-chambers, Victoria-street, London, S.W.
1867. ‡Henderson, Alexander. Dundee.
1845. ‡Henderson, Andrew. 120 Gloucester-place, Portman-square, London.
1866. ‡HENDERSON, JAMES, jun. Dundee.
1856. ‡HENNESSY, HENRY G., F.R.S., M.R.I.A. 86 St. Stephen's-green, Dublin.
1857. †Hennessy, John Pope. Inner Temple, London, E.C.
Henry, Franklin. Portland-street, Manchester.
Henry, J. Snowdon. East Dene, Bonchurch, Isle of Wight.
Henry, Mitchell. Stratheden House, Hyde Park, London, W.
*HENRY, WILLIAM CHARLES, M.D., F.R.S., F.G.S., F.R.G.S. Haffield, near Ledbury, Herefordshire.
1870. ‡Henty, William. Norfolk-terrace, Brighton.
HENWOOD, WILLIAM JORY, F.R.S., F.G.S. 3 Clarence-place, Penzance.
1855. *Hepburn, J. Gotch, LL.B., F.C.S. Sidcup-place, Sidcup, Kent.
1855. ‡Hepburn, Robert. 9 Portland-place, London, W.
Hepburn, Thomas. Clapham, London, S.W.
1871. ‡Hepburn, Thomas H. St. Mary's Cray, Kent.
Hepworth, John Mason. Ackworth, Yorkshire.
1856. ‡Hepworth, Rev. Robert. 2 St. James's-square, Cheltenham.
*Herbert, Thomas. The Park, Nottingham.
1852. †Herdman, John. 9 Wellington-place, Belfast.
1866. §Herrick, Perry. Bean Manor Park, Loughborough.
1871. *HERSCHEL, Professor ALEXANDER S., B.A. College of Science, Newcastle-on-Tyne.
1865. ‡Heslop, Dr. Birmingham.

Year of Election.

1863. ‡Heslop, Joseph. Pilgrim-street, Newcastle-on-Tyne.
1832. ‡Hewitson, William C. Oatlands, Surrey.
Hey, Rev. William, M.A., F.C.P.S. Clifton, York.
1866. *Heymann, Albert. West Bridgford, Nottinghamshire.
1866. ‡Heymann, L. West Bridgford, Nottinghamshire.
1861. *Heywood, Arthur Henry. Elleray, Windermere.
*HEYWOOD, JAMES, F.R.S., F.G.S., F.S.A., F.R.G.S. 26 Palace-gardens, Kensington, London, W.
1861 *Heywood, Oliver. Claremont, Manchester.
Heywood, Thomas Percival. Claremont, Manchester.
1870. *Heyworth, Lawrence. Yewtree, Liverpool.
1864. *HIERN, W. P., M.A. 1 Foxton-villa, Richmond, Surrey.
1854. *Higgin, Edward.
1861. *Higgin, James. Lancaster-avenue, Fennel-street, Manchester.
Higginbotham, Samuel. 4 Springfield-court, Queen-street, Glasgow.
1866. ‡Higginbottom, John. Nottingham.
1871. †HIGGINS, CLEMENT, F.C.S. 27 St. John's-park, Upper Holloway, London, N.
1861. ‡Higgins, George. Mount House, Higher Broughton, Manchester.
1854. ‡HIGGINS, Rev. HENRY H., M.A. The Asylum, Rainhill, Liverpool.
1861. *Higgins, James. Stocks House, Cheetham, Manchester.
1870. ‡Higginson, Alfred. 44 Upper Parliament-street, Liverpool.
1842. *Higson, Peter, F.G.S., H.M. Inspector of Mines. The Brooklands, Swinton, near Manchester.
1870. §Highton, Rev. H. 2 The Cedars, Putney, S.W.
Hildyard, Rev. James, B.D., F.C.P.S. Ingoldsby, near Grantham, Lincolnshire.
Hill, Arthur. Bruce Castle, Tottenham, London, N.
1872. §Hill, Charles. Rockhurst, West Hoathley, East Grinstead.
*Hill, Rev. Edward, M.A., F.G.S. Sheering Rectory, Harlow.
1857. §Hill, John, M.Inst.C.E., M.R.I.A., F.R.G.S.I. County Surveyor's Office, Ennis, Ireland.
1871. §Hill, Lawrence. The Knowe, Greenock.
*HILL, Sir ROWLAND, K.C.B., D.C.L., F.R.S., F.R.A.S. Hampstead, London, N.W.
1864. ‡Hill, William. Combe Hay, Bristol.
1863 ‡Hills, F. C. Chemical Works, Deptford, Kent, S.E.
1871. §Hills, Graham H., Staff-Commander R.N. 4 Bentley-road, Princes Park, Liverpool.
1871. *Hills, Thomas Hyde. 338 Oxford-street, London, W.
1858. ‡HINCKS, Rev. THOMAS, B.A., F.R.S. Mountside, Leeds.
1870. ‡Hinde, G. J. Buenos Ayres.
Hindley, Rev. H. J. Edlington, Lincolnshire.
1852. *HINDMARSH, FREDERICK, F.G.S., F.R.G.S. 4 New Inn, Strand, London, W.C.
*Hindmarsh, Luke. Alnbank House, Alnwick.
1865. ‡Hinds, James, M.D. Queen's College, Birmingham.
1863. ‡Hinds, William, M.D. Parade, Birmingham.
1861. *Hinmers, William. Cleveland House, Birkdale, Southport.
1858. §Hirst, John, jun. Dobcross, near Manchester.
1861. *HIRST, T. ARCHER, Ph.D., F.R.S., F.R.A.S. Royal Naval College, Greenwich, S.E.; and Athenæum Club, Pall Mall, London, S.W.
1856. ‡Hitch, Samuel, M.D. Sandywell Park, Gloucestershire.
1860. ‡Hitchman, John. Leamington.
1870. ‡Hitchman, William, M.D. 29 Erskine-street, Liverpool.
*Hoare, Rev. George Tooker. Godstone Rectory, Redhill.

Year of Election.

Hoare, J. Gurney. Hampstead, London, N.W.
1864. ‡Hobhouse, Arthur Fane. 24 Cadogan-place, London, S.W.
1864. ‡Hobhouse, Charles Parry. 24 Cadogan-place, London, S.W.
1864. ‡Hobhouse, Henry William. 24 Cadogan-place, London, S.W.
1863. §Hobson, A. S., F.C.S. 3 Upper Heathfield-terrace, Turnham Green, London, W.
1866. ‡Hockin, Charles, M.D. 8 Avenue-road, St. John's Wood, London.
1852. ‡Hodges, John F., M.D., Professor of Agriculture in Queen's College, Belfast. 23 Queen-street, Belfast.
1863. *Hodgkin, Thomas. Benwell Dene, Newcastle-on-Tyne.
1863. ‡Hodgson, Robert. Whitburn, Sunderland.
1863. ‡Hodgson, R. W. North Dene, Gateshead.
Hodgson, Thomas. Market-street, York.
1839. ‡Hodgson, W. B., LL.D., F.R.A.S. 41 Grove-end-road, St. John's Wood, London, N.W.
1860. ‡Hogan, Rev. A. R., M.A. Watlington Vicarage, Oxfordshire.
1865. *Hofmann, Augustus William, LL.D, Ph.D., F.R.S., F.C.S. 10 Dorotheen Strasse, Berlin.
Hogan, William, M.A., M.R.I.A. Haddington-terrace, Kingstown, near Dublin.
1861. †Holcroft, George, C.E. Red-lion-court, St. Ann's-square, Manchester.
1854. *Holcroft, George. Byron's-court, St. Mary's-gate, Manchester.
1856. ‡Holland, Henry. Dumbleton, Evesham.
1858. §Holland, Loton, F.R.G.S. 6 Queen's-villas, Windsor.
*Holland, Philip H. Burial Acts Office, 13 Great George-street, Westminster, S.W.
1865. ‡Holliday, William. New-street, Birmingham.
*Hollingsworth, John, M.R.C.S. Maidenstone House, Maidenstone Hill, Greenwich, S.E.
1866. *Holmes, Charles. London-road, Derby.
1870. ‡Holt, William D. 23 Edge-lane, Liverpool.
*Hone, Nathaniel, M.R.I.A. Bank of Ireland, Dublin.
1858. ‡Hook, The Very Rev. W. F., D.D., Dean of Chichester. Chichester.
1847. †Hooker, Joseph Dalton, C.B., M.D., D.C.L., LL.D., F.R.S., V.P.L.S., F.G.S., F.R.G.S. Royal Gardens, Kew.
1865. *Hooper, John P. 7 Pall Mall East, London, S.W.
1861. §Hooper, William. 7 Pall Mall East, London, S.W.
1856. ‡Hooton, Jonathan. 80 Great Ducie-street, Manchester.
1842. Hope, Thomas Arthur. Stanton, Bebington, Cheshire.
1869. §Hope, William, V.C. Parsloes, Barking, Essex.
1865. †Hopkins, J. S. Jesmond Grove, Edgbaston, Birmingham.
1870. *Hopkinson, John. Woodlea, Beech-lanes, Birmingham.
1871. §Hopkinson, John, F.G.S. 8 Lawn-road, Haverstock-hill, London, N.W.
1858. ‡Hopkinson, Joseph, jun. Britannia Works, Huddersfield.
Hornby, Hugh. Sandown, Liverpool.
1864. *Horner, Rev. J. J. H. St. Lawrence, Isle of Wight.
1858. *Horsfall, Abraham. Manor House, Whitkirks, near Leeds.
1854. †Horsfall, Thomas Berry. Bellamour Park, Rugeley.
1856. ‡Horsley, John H. 389 High-street, Cheltenham.
Hotham, Rev. Charles, M.A., F.L.S. Roos, Patrington, Yorkshire.
1868. ‡Hotson, W. C. Upper King-street, Norwich.
1859. ‡Hough, Joseph. Wrottesley, near Wolverhampton.
Houghton, The Right Hon. Lord, D.C.L., F.R.S., F.R.G.S. 16 Upper Brook-street, London, W.
Houghton, James. 41 Rodney-street, Liverpool.

Year of Election

1858. ‡Hounsfield, James. Hemsworth, Pontefract.
Hovenden, W. F., M.A. Bath.
1859. ‡Howard, Captain John Henry, R.N. The Deanery, Lichfield.
1863. ‡Howard, Philip Henry. Corby Castle, Carlisle.
1857. ‡Howell, Henry H., F.G.S. Museum of Practical Geology, Jermyn-street, London, S.W.
1868. ‡Howell, Rev. Canon Hinds. Drayton Rectory, near Norwich.
1865. *Howlett, Rev. Frederick, F.R.A.S. East Tisted Rectory, Alton, Hants.
1863. ‡Howorth, H. H. Derby House, Eccles, Manchester.
1854. ‡Howson, Very Rev. J. S., Dean of Chester. Chester.
1870. ‡Hubback, Joseph. 1 Brunswick-street, Liverpool.
1835. *Hudson, Henry, M.D., M.R.I.A. Glenville, Fermoy, Co. Cork.
1842. §Hudson, Robert, F.R.S., F.G.S., F.L.S. Clapham Common, London, S.W.
1867. ‡Hudson, William H. H., M.A. 19 Bennett's-hill, Doctors Commons, London, E.C.; and St. John's College, Cambridge.
1858. *Huggins, William, D.C.L., Oxon. LL.D. Camb., F.R.S., F.R.A.S. Upper Tulse-hill, Brixton, London, S.W.
1857. ‡Huggon, William. 30 Park-row, Leeds.
Hughes, D. Abraham. 9 Gray's-inn-square, London, W.C.
Hughes, Frederick Robert.
1871. *Hughes, George Pringle. Middleton Hall, Wooler, Northumberland.
1870. ‡Hughes, Lewis. 38 St. Domingo-grove, Liverpool.
1868. §Hughes, T. M'K., M.A., F.G.S. Woodwardian Professor of Geology in the University of Cambridge.
1863. ‡Hughes, T. W. 4 Hawthorn-terrace, Newcastle-on-Tyne.
1865. ‡Hughes, W. R., F.L.S., Treasurer of the Borough of Birmingham.
Hull, Arthur H. 18 Norfolk-road, Brighton.
1867. §Hull, Edward, M.A., F.R.S., F.G.S. Director of the Geological Survey of Ireland, and Professor of Geology in the Royal College of Science. 14 Hume-street, Dublin.
*Hull, William Darley. 36 Queen's-gate-terrace, South Kensington, London, W.
*Hulse, Sir Edward, Bart., D.C.L. 47 Portland-place, London, W.; and Breamore House, Salisbury.
1861. ‡Hume, Rev. Abraham, D.C.L., LL.D., F.S.A. All Soul's Vicarage, Rupert-lane, Liverpool.
1856. ‡Humphries, David James. 1 Keynsham-parade, Cheltenham.
1862. *Humphry, George Murray, M.D., F.R.S., Professor of Anatomy in the University of Cambridge. The Leys, Cambridge.
1863. *Hunt, Augustus H., M.A., Ph.D. Birtley House, Chester-le-Street, Fence Houses, Co. Durham.
1865. ‡Hunt, J. P. Gospel Oak Works, Tipton.
1840. ‡Hunt, Robert, F.R.S., Keeper of the Mining Records. Museum of Practical Geology, Jermyn-street, London, S.W.
1864. ‡Hunt, W. 72 Pulteney-street, Bath.
Hunter, Andrew Galloway. Denholm, Hawick, N.B.
1868. ‡Hunter, Christopher. Alliance Insurance Office, North Shields.
1867. ‡Hunter, David. Blackness, Dundee.
1869. *Hunter, Rev. Robert, F.G.S. 9 Mecklenburg-street, London, W.C.
1859. ‡*Hunter, Dr. Thomas, Deputy Inspector-General of Army Hospitals.*
1855. *Hunter, Thomas O. 24 Forsyth-street, Greenock.
1863. ‡Huntsman, Benjaman. West Retford Hall, Retford.
1869. §Hurst, George. Bedford.
1861. *Hurst, Wm. John. Drumaness Mills, Ballynahinch, Lisburn, Ireland.

Year of
Election.

1870. ‡Hurter, Dr. Ferdinand. Appleton, Widnes, near Warrington.
Husband, William Dalla. Coney-street, York.
1868. *Hutchison, Robert. Carlowrie, Kirkliston, N.B.
1863. ‡HUTT, The Right Hon. Sir W., K.C.B., M.P. Gibside, Gateshead.
Hutton, Crompton. Putney-park, Surrey, S.W.
1864. *Hutton, Darnton. (Care of Arthur Lupton, Esq., Headingley, near Leeds.)
1857. ‡Hutton, Henry D. 10 Lower Mountjoy-street, Dublin.
Hutton, Henry. Edenfield, Dundrum, Co. Dublin.
1861. *Hutton, T. Maxwell. Summerhill, Dublin.
1852. ‡HUXLEY, THOMAS HENRY, Ph.D., LL.D., F.R.S., F.L.S., F.G.S., Professor of Natural History in the Royal School of Mines. 4 Marlborough-place, London, N.W.
Hyde, Edward. Dukinfield, near Manchester.
1871. *Hyett, Francis A. 13 Hereford-square, Old Brompton, London, S.W.
Hyett, William Henry, F.R.S. Painswick, near Stroud, Gloucestershire.
1847. ‡Hyndman, George C. 5 Howard-street, Belfast.

Ihne, William, Ph.D. Heidelberg.
1861. ‡Iles, Rev. J. H. Rectory, Wolverhampton.
1858. ‡Ingham, Henry. Wortley, near Leeds.
1871. ‡INGLIS, The Right Hon. JOHN, D.C.L., LL.D., Lord Justice General of Scotland. Edinburgh.
1858. *Ingram, Hugo Francis Meynell. Temple Newsam, Leeds.
1852. ‡INGRAM, J. K., LL.D., M.R.I.A., Regius Professor of Greek. Trinity College, Dublin.
1854. *INMAN, THOMAS, M.D. 12 Rodney-street, Liverpool.
1870. *Inman, William. Upton Manor, Liverpool.
Ireland, R. S., M.D. 121 Stephen's-green, Dublin.
1857. ‡Irvine, Hans, M.A., M.B. 1 Rutland-square, Dublin.
Irwin, Rev. Alexander, M.A. Armagh, Ireland.
1862. ‡ISELIN, J. F., M.A., F.G.S. 52 Stockwell-park-road, London, S.W.
1863. *Ivory, Thomas. 23 Walker-street, Edinburgh.

1865. ‡Jabet, George. Wellington-road, Handsworth, Birmingham.
1870. ‡Jack, James. 26 Abercromby-square, Liverpool.
1859. §Jack, John, M.A. Belhelvie-by-Whitecairns, Aberdeenshire.
1863. *Jackson-Gwilt, Mrs. H. 24 Hereford-square, Gloucester-road, Brompton, London, S.W.
1865. ‡*Jackson, Edwin.*
1866. §Jackson, H. W. Springfield, Tooting, Surrey, S.W.
1869. §Jackson, Moses. The Vale, Ramsgate.
Jackson, Professor Thomas, LL.D. St. Andrew's, Scotland.
Jacob, Arthur, M.D. 23 Ely-place, Dublin.
1852. ‡JACOBS, BETHEL. 40 George-street, Hull.
1867. *Jaffe, David Joseph. (Messrs. Jaffe Brothers) Belfast.
1865. *Jaffray, John. Park-grove, Birmingham.
1872. §James, Christopher. 8 Laurence Pountney Hill, London, E.C.
1859. ‡James, Edward. 9 Gascoyne-terrace, Plymouth.
1860. ‡James, Edward H. 9 Gascoyne-terrace, Plymouth.
JAMES, Colonel Sir HENRY, R.E., F.R.S., F.G.S., M.R.I.A. Ordnance Survey Office, Southampton.
1863. *JAMES, Sir WALTER, Bart., F.G.S. 6 Whitehall-gardens, London, S.W.
1858. ‡James, William C. 9 Gascoyne-terrace, Plymouth.
1863. ‡Jameson, John Henry. 10 Catherine-terrace, Gateshead.

Year of Election.

1859. *Jamieson, Thomas F., F.G.S. Ellon, Aberdeenshire.
1850. ‡Jardine, Alexander. Jardine Hall, Lockerby, Dumfriesshire.
1870. ‡Jardine, Edward. Beach Lawn, Waterloo, Liverpool.
Jardine, James, C.E., F.R.A.S. Edinburgh.
*JARDINE, Sir WILLIAM, Bart., F.R.S. L. & E., F.L.S. Jardine Hall, Applegarth by Lockerby, Dumfriesshire.
1853. *Jarratt, Rev. Canon J., M.A. North Cave, near Brough, Yorkshire.
JARRETT, Rev. THOMAS, M.A., Professor of Arabic in the University of Cambridge. Trunch, Norfolk.
1870. §Jarrold, John James. London-street, Norwich.
1862. ‡Jeakes, Rev. James, M.A. 54 Argyll-road, Kensington, W.
Jebb, Rev. John. Peterstow Rectory, Ross, Herefordshire.
1868. ‡Jecks, Charles. Billing-road, Northampton.
1842. **Jee, Alfred S.*
1870. ‡Jeffery, F. J. Liverpool.
1856. ‡Jeffery, Henry, M.A. 438 High-street, Cheltenham.
1855. *Jeffray, John. 193 St. Vincent-street, Glasgow.
1867. ‡Jeffreys, Howel, M.A., F.R.A.S. 5 Brick-court, Temple, E.C.; and 25 Devonshire-place, Portland-place, London, W.
1861. *JEFFREYS, J. GWYN, F.R.S., F.L.S., F.G.S., F.R.G.S. 25 Devonshire-place, Portland-place, London, W.; and Ware Priory, Herts.
1852. ‡JELLETT, Rev. JOHN H., M.A., M.R.I.A., Professor of Natural Philosophy in Trinity College, Dublin. 64 Upper Leeson-street, Dublin.
1842. Jellicorse, John. Chaseley, near Rugeley, Staffordshire.
1864. ‡Jelly, Dr. W. Paston Hall, near Peterborough.
1862. §JENKIN, H. C. FLEEMING, F.R.S., Professor of Civil Engineering in the University of Edinburgh. 5 Fettes-row, Edinburgh.
1864. §JENKINS, Captain GRIFFITH, C.B., F.R.G.S. Derwin, Welshpool.
*Jenkyns, Rev. Henry, D.D. The College, Durham.
Jennette, Matthew. 106 Conway-street, Birkenhead.
1852. ‡Jennings, Francis M., F.G.S., M.R.I.A. Brown-street, Cork.
1872. §Jennings, W. Grand Hotel, Brighton.
1870. ‡Jerdon, T. C. (Care of Mr. H. S. King, 45 Pall Mall, London, S.W.)
*Jerram, Rev. S. John, M.A. Chobham Vicarage, Farnborough Station.
1872. §Jesson, Thomas. 3 Clarendon-crescent, Brighton.
Jessop, William, jun. Butterley Hall, Derbyshire.
1870. *JEVONS, W. STANLEY, M.A., F.R.S., Professor of Political Economy in Owens College, Manchester. Parsonage-road, Writhington, Manchester.
1872. *Joad, George C. Patching, Arundel, Sussex.
1871. *Johnson, David. Irvon Villa, Grosvenor-road, Wrexham.
1866. §Johnson, John. Knighton Fields, Leicester.
1866. §Johnson, John G. 18A Basinghall-street, London, E.C.
1868. ‡Johnson, J. Godwin. St. Giles's-Street, Norwich.
1872. §Johnson, J. T. 27 Dale-street, Manchester.
1868. ‡*Johnson, Randall J.*
1863. ‡Johnson, R. S. Hanwell, Fence Houses, Durham.
1861. ‡Johnson, Richard. 27 Dale-street, Manchester.
1870. §Johnson, Richard C. Warren Side, Blundell Sands, Liverpool.
*Johnson, Thomas. The Hermitage, Frodsham, Cheshire.
1864. ‡Johnson, Thomas. 30 Belgrave-street, Commercial-road, London, E.
Johnson, William. The Wynds Point, Colwall, Malvern, Worcestershire.

Year of Election.

1861. ‡Johnson, William Beckett. Woodlands Bank, near Altrincham.
JOHNSTON, ALEXANDER ROBERT, F.R.S. Heatherley, near Wokingham.
1871. ‡Johnson, A. Keith. 74 Strand, London, W.C.
1864. ‡Johnston, David. 13 Marlborough-buildings, Bath.
Johnston, Edward. Field House, Chester.
1865. *Johnston, G. J. 34 Waterloo-street, Birmingham.
1859. ‡Johnston, James. Newmill, Elgin, N.B.
1864. ‡Johnston, James. Manor House, Northend, Hampstead, London, N.
*Johnstone, James. Aloa House, by Stirling.
1864. ‡Johnstone, John. 1 Barnard-villas, Bath.
1864. ‡Jolly, Thomas. Park View-villas, Bath.
1871. §Jolly, William (H. M. Inspector). Inverness.
1849. ‡Jones, Baynham. Selkirk Villa, Cheltenham.
1856. ‡Jones, C. W. 7 Grosvenor-place, Cheltenham.
1854. ‡Jones, Rev. Henry H. Cemetery, Manchester.
1854. ‡Jones, John. 70 Rodney-street, Liverpool.
1864. §Jones, John, F.G.S. Royal Exchange, Middlesborough.
1865. ‡Jones, John. 49 Union-passage, Birmingham.
*Jones, Robert. 2 Castle-street, Liverpool.
1854. *Jones, R. L. 6 Sunnyside, Princes Park, Liverpool.
1847. ‡JONES, THOMAS RYMER, F.R.S., Professor of Comparative Anatomy in King's College. 52 Cornwall-road, Westbourne Park, London, W.
1860. ‡JONES, T. RUPERT, F.R.S., F.G.S., Professor of Geology and Mineralogy, Royal Military and Staff Colleges, Sandhurst. 5 College-terrace, York Town, Surrey.
1864. §JONES, Sir WILLOUGHBY, Bart, F.R.G.S. Cranmer Hall, Fakenham, Norfolk.
*Joule, Benjamin St. John B. 28 Leicester-street, Southport, Lancashire.
1842. *JOULE, JAMES PRESCOTT, LL.D., F.R.S., F.C.S., PRESIDENT ELECT. 5 Cliff-point, Higher Broughton, Manchester.
1872. §Joy, Algernon. 17 Parliament-street, Westminster, S.W.
1848. *Joy, Rev. Charles Ashfield. Grove Parsonage, near Wantage, Berkshire.
Joy, Henry Holmes, LL.D., Q.C., M.R.I.A. 17 Mountjoy-square East, Dublin.
Joy, Rev. John Holmes, M.A. 3 Coloney-terrace, Tunbridge Wells.
1847. ‡JOWETT, Rev. B., M.A., Regius Professor of Greek in the University of Oxford. Balliol College, Oxford.
1858. ‡Jowett, John, jun. Leeds.
*Jubb, Abraham. Halifax.
1870. ‡Judd, John Wesley, F.G.S. 6 Manor-view, Brixton.
1863. ‡Jukes, Rev. Andrew. Spring Bank, Hull.

1868. *Kaines, Joseph, F.A.S.L. 8 Osborne-road, Stroud Green-lane, Hornsey.
KANE, Sir ROBERT, M.D., F.R.S., M.R.I.A., Principal of the Royal College of Cork. 51 Stephen's-green, Dublin.
1857. ‡Kavanagh, James W. Grenville, Rathgar, Ireland.
1859. ‡Kay, David, F.R.G.S. 19 Upper Phillimore-place, Kensington, W.
Kay, John Cunliff. Fairfield Hall, near Skipton.
*Kay, John Robinson. Walmersley House, Bury, Lancashire.

Year of Election.

Kay, Robert. Haugh Bank, Bolton-le-Moors.
1847. *Kay, Rev. William, D.D. Great Leighs Rectory, Chelmsford.
1856. ‡Kay-Shuttleworth, Sir James, Bart. Gawthorpe, Burnley.
1855. ‡Kaye, Robert. Mill Brae, Moodies Burn, by Glasgow.
1872. §Keames, William M. 5 Lower-rock-gardens, Brighton.
1855. ‡Keddie, William. 15 North-street, Mungo-street, Glasgow.
1866. ‡Keene, Alfred. Eastnoor House, Leamington.
1850. ‡KELLAND, Rev. PHILIP, M.A., F.R.S. L. & E., Professor of Mathematics in the University of Edinburgh. 20 Clarendon-crescent, Edinburgh.
1864. *Kelly, W. M., M.D. 11 The Crescent, Taunton, Somerset.
1842. Kelsall, J. Rochdale, Lancashire.
1864. *Kemble, Rev. Charles, M.A. Vellore, Bath.
1853. ‡Kemp, Rev. Henry William, B.A. The Charter House, Hull.
1858. ‡Kemplay, Christopher. Leeds.
1857. ‡Kennedy, Lieut-Colonel John Pitt. 20 Torrington-square, Bloomsbury, London, W.C.
Kenny, Matthias, M.D. 3 Clifton-terrace, Monkstown, Co. Dublin.
1865. ‡Kenrick, William. Norfolk-road, Edgbaston, Birmingham.
Kent, J. C. Levant Lodge, Earl's Croome, Worcester.
1857. ‡Kent, William T., M.R.D.S. 51 Rutland-square, Dublin.
1857. ‡Kenworth, James Ryley. 7 Pembroke-place, Liverpool.
1857. *Ker, André Allen Murray. Newbliss House, Newbliss, Ireland.
1855. *Ker, Robert. Auchinraith, by Hamilton, Scotland.
1865. *Kerr, William D., M.D., R.N. Bonnyrigg, Edinburgh.
1868. ‡Kerrison, Roger. Crown Bank, Norwich.
1869. *Kesselmeyer, Charles A. 1 Peter-street, Manchester.
1869. *Kesselmeyer, William Johannes. 1 Peter-street, Manchester.
1861. *Keymer, John. Parker-street, Manchester.
1865. *Kinahan, Edward Hudson. 11 Merrion-square North, Dublin.
1860. ‡KINAHAN, G. HENRY, M.R.I.A. Geological Survey of Ireland. 14 Hume-street, Dublin.
1858. ‡Kincaid, Henry Ellis, M.A. 8 Lyddon-terrace, Leeds.
1871. *King, Herbert Poole. Theological College, Salisbury.
1855. ‡King, James. Levernholme, Hurlet, Glasgow.
1870. §King, John Thomson, C.E. 4 Clayton-square, Liverpool.
King, Joseph. Blundell Sands, Liverpool.
1864. §KING, KELBURNE, M.D. 27 George-street; and Royal Institution, Hull.
1860. *King, Mervyn Kersteman. Avonside, Clifton Down, Bristol.
1872. *King, Mrs. E. M. 34 Cornwall-road, Westbourne-park, London, W.
1842. KING, RICHARD, M.D. 12 Bulstrode-street, London, W.
King, Rev. Samuel, M.A., F.R.A.S. St. Aubins, Jersey.
1870. ‡King, William. 13 Adelaide-terrace, Waterloo, Liverpool.
King, William Poole, F.G.S. Avonside, Clifton, Bristol.
1869. ‡Kingdon, K. Taddiford, Exeter.
1862. ‡KINGSLEY, Rev. Canon CHARLES, M.A., D.C.L., F.L.S., F.G.S. Eversley Rectory, Winchfield.
1861. ‡Kingsley, John. 30 St. Ann's-street, Manchester.
1835. Kingstone, A. John, M.A. Mosstown, Longford, Ireland.
1867. ‡Kinloch, Colonel. Kirriemuir, Logie, Scotland.
1870. ‡Kinsman, William R. Branch Bank of England, Liverpool.
1867. *KINNAIRD, The Hon. ARTHUR FITZGERALD, M.P. 1 Pall Mall East, London, S.W.; and Rossie Priory, Inchture, Perthshire.
1863. ‡KINNAIRD, The Right Hon. Lord., K.T., F.G.S. Rossie Priory, Inchture, Perthshire.
Kinnear, J. G., F.R.S.E. Glasgow.

Year of Election.

1863. ‡Kirkaldy, David. 28 Bartholomew-road North, London, N.W.
1860. ‡KIRKMAN, Rev. THOMAS P., M.A., F.R.S. Croft Rectory, near Warrington.
Kirkpatrick, Rev. W. B., D.D. 48 North Great George-street, Dublin.
1870. ‡Kitchener, Frank E. Rugby.
1869. ‡Knapman, Edward. The Vineyard, Castle-street, Exeter.
1870. §Kneeshaw, Henry. 2 Gambier-terrace, Liverpool.
Knipe, J. A. Botcherby, Carlisle.
1872. *Knott, George, LL.B., F.R.A.S. Woodcroft, Cuckfield, Hayward's Heath, Sussex.
1842. Knowles, John. Old Trafford Bank House, Old Trafford, Manchester.
1870. ‡Knowles, Rev. J. L. Grove Villa, Bushey, Herts.
*Knox, George James. 37 Liverpool-street, Dover.
1835. Knox, Thomas B. Union Club, Trafalgar-square, London, W.C.
1872. §Kowles, James. The Hollies, Clapham Common, London, S.W.
1870. ‡Kynaston, Josiah W. St. Helens, Lancashire.
1865. ‡Kynnersley, J. C. S. The Leveretts, Handsworth, Birmingham.

1858. §Lace, Francis John. Stone Gapp, Cross-hill, Leeds.
1862. ‡Lackerstein, Dr. (Care of Messrs. Smith and Elder, 15 Waterloo-place, London, S.W.)
1859. §Ladd, William, F.R.A.S. 11 & 13 Beak-street, Regent-street, London, W.
1850. ‡Laing, David, F.S.A. Scotl. Signet Library, Edinburgh.
1870. ‡Laird, H. H. Birkenhead.
Laird, John, M.P. Hamilton-square, Birkenhead.
1870. §Laird, John, jun. Grosvenor-road, Claughton, Birkenhead.
1859. ‡Lalor, John Joseph, M.R.I.A. 2 Longford-terrace, Monkstown, Co. Dublin.
1846. *Laming, Richard. Flaucham, near Bognor, Sussex.
1870. §Lamport, Charles. Upper Norwood, Surrey.
1871. §Lancaster, Edward. Karesforth Hall, Barnesley.
1859. ‡Lang, Rev. John Marshall. Bank House, Morningside, Edinburgh.
1864. §Lang, Robert. Mancombe, Henbury, Bristol.
1870. ‡Langton, Charles. Barkhill, Aigburth, Liverpool.
*Langton, William. Manchester.
1840. ‡LANKESTER, EDWIN, M.D., LL.D., F.R.S., F.L.S. 68 Belsize-park, N.W.
1865. §LANKESTER, E. RAY. Exeter College, Oxford.
*LARCOM, Major-General Sir THOMAS AISKEW, K.C.B., R.E., F.R.S., M.R.I.A. Heathfield House, Fareham, Hants.
LASSELL, WILLIAM, F.R.S., F.R.A.S. Ray Lodge, Maidenhead.
1861. *Latham, Arthur G. 24 Cross-street, Manchester.
1870. *Latham, Baldwin. 7 Westminster-chambers, Westminster, S.W.
1845. ‡Latham, Robert G., M.A., M.D., F.R.S. 96 Disraeli-road, Putney, S.W.
*La Touche, David Charles, M.R.I.A. Castle-street, Dublin.
1870. ‡Laughton, John Knox, M.A., F.R.A.S., F.R.G.S. Royal Naval College, Portsmouth.
1870. *Law, Channell. 5 Champion-park, Camberwell, London, S.E.
1857. ‡Law, Hugh. 4 Great Denmark-street, Dublin.
1862. ‡Law, Rev. James Edmund, M.A. Little Shelford, Cambridgeshire.
Lawley, The Hon. Francis Charles. Escrick Park, near York.
Lawley, The Hon. Stephen Willoughby. Escrick Park, near York.
1870. ‡Lawrence, Edward. Aigburth, Liverpool.

Year of Election.

1869. ‡Lawson, Henry. 8 Nottingham-place, London, W.
1857. ‡Lawson, James A., LL.D., M.R.I.A. 27 Fitzwilliam-street, Dublin.
1868. *LAWSON, M. ALEXANDER, M.A., F.L.S., Professor of Botany in the University of Oxford. Botanic Gardens, Oxford.
1863. ‡Lawton, Benjamin C. Neville Chambers, 44 Westgate-street, Newcastle-upon-Tyne.
1853. ‡Lawton, William. 8 Manor House-street, Hull.
LAYCOCK, THOMAS, M.D., Professor of the Practice of Physic in the University of Edinburgh. 4 Rutland-street, Edinburgh.
1865. ‡Lea, Henry. 35 Paradise-street, Birmingham.
1857. ‡Leach, Capt. R. E. Mountjoy, Phœnix Park, Dublin.
Leadbetter, John. Glasgow.
1870. *Leaf, Charles John, F.L.S., F.G.S., F.S.A. Old Change, London, E.C.; and Painshill, Cobham.
1847. *LEATHAM, EDWARD ALDAM, M.P. Whitley Hall, Huddersfield; and 46 Eaton-square, London, S.W.
1858. ‡Leather, George. Knostrop, near Leeds.
*Leather, John Towlerton, F.S.A. Leventhorpe Hall, near Leeds.
1858. ‡Leather, John W. Newton Green, Leeds.
1863. ‡Leavers, J. W. The Park, Nottingham.
1872. §LEBOUR, G. A., F.G.S. Geological Survey Office, Jermyn-street, London, S.W.
1858. *Le Cappelain, John. Wood-lane, Highgate, London, N.
1858. ‡Ledgard, William. Potter Newton, near Leeds.
1842. Lee, Daniel. Springfield House, Pendlebury, Manchester.
1861. ‡Lee, Henry. Irwell House, Lower Broughton, Manchester.
Lee, Henry, M.D. Weatheroak, Alve Church, near Bromsgrove.
1853. *LEE, JOHN EDWARD, F.G.S., F.S.A. Villa Syracusa, Torquay.
1859. ‡Lees, William. Link Vale Lodge, Viewforth, Edinburgh.
*Leese, Joseph. Glenfield, Altrincham, Manchester.
*Leeson, Henry B., M.A., M.D., F.R.S., F.C.S The Maples, Bonchurch, Isle of Wight.
1872. §LEFEVRE, G. SHAW, M.P., F.R.G.S. 18 Spring-gardens, London, S.W.
*LEFROY, J. HENRY, Major-General, R.A., F.R.S., F.R.G.S., Director-General of Ordnance. 82 Queen's-gate, London, W.
*Legh, George Cornwall, M.P. High Legh Hall, Cheshire; and 43 Curzon-street, Mayfair, London, W.
1869. ‡Le Grice, A. J. Trereife, Penzance.
1868. ‡LEICESTER, The Right Hon. The Earl of. Holkham, Norfolk.
1856. ‡LEIGH, The Right Hon. Lord, D.C.L. 37 Portman-square, London, W.; and Stoneleigh Abbey, Kenilworth.
1861. *Leigh, Henry. Moorfield, Swinton, near Manchester.
1870. §Leighton, Andrew. 35 High-park-street, Liverpool.
*LEINSTER, AUGUSTUS FREDERICK, Duke of, M.R.I.A. 6 Carlton-house-terrace, London, S.W.; and Carton, Maynooth, Ireland.
1867. §Leishman, James. Gateacre Hall, Liverpool.
1870. ‡Leister, G. F. Gresbourn House, Liverpool.
1859. ‡Leith, Alexander. Glenkindie, Inverkindie, N.B.
1860. ‡Lempriere, Charles, D.C.L. St. John's College, Oxford.
1863. *LENDY, Capt. AUGUSTE FREDERIC, F.L.S., F.G.S. Sunbury House, Sunbury, Middlesex.
1867. ‡Leng, John. "Advertiser" Office, Dundee.
1861. ‡Lennox, A. C. W. 7 Beaufort-gardens, Brompton, London, S.W.
Lentaigne, John, M.D. Tallaght House, Co. Dublin; and 14 Great Dominick-street, Dublin.

Year of Election.

Lentaigne, Joseph. 12 Great Denmark-street, Dublin.
1871. §Leonard, Hugh, M.R.I.A., Geological Survey of Ireland. 14 Hume-street, Dublin.
1861. ‡Leppoc, Henry Julius. Kersal Crag, near Manchester.
1872. §Lermit, Rev. Dr. School House, Dedham.
1871. ‡Leslie, Alexander, C.E. 72 George-street, Edinburgh.
1856. ‡Leslie, Colonel J. Forbes. Rothienorman, Aberdeenshire.
1852. ‡LESLIE, T. E. CLIFFE, LL.B., Professor of Jurisprudence and Political Economy, Queen's College, Belfast.
1866. §LEVI, Dr. LEONE, F.S.A., F.S.S., Professor of Commercial Law in King's College, London. 10 Farrar's-building, Temple, London, E.C.
1870. ‡LEWIS, ALFRED LIONEL. 151 Church-road, De Beauvoir Town, London, N.
1853. ‡Liddell, George William Moore. Sutton House, near Hull.
1860. ‡LIDDELL, The Very Rev. H. G., D.D., Dean of Christ Church, Oxford.
1855. ‡Liddell, John. 8 Clelland-street, Glasgow.
1859. ‡Ligertwood, George. Blair by Summerhill, Aberdeen.
1864. §LIGHTBODY, ROBERT, F.G.S. Ludlow, Salop.
1862. ‡LILFORD, The Right Hon. Lord, F.L.S. Lilford Hall, Oundle, Northamptonshire.
*LIMERICK, CHARLES GRAVES, D.D., M.R.I.A., Lord Bishop of. The Palace, Henry-street, Limerick.
*Lindsay, Charles. Ridge Park, Lanark.
1855. *Lindsay, John H. (Care of James Jarvie, Esq., 7 Steven-street, Glasgow.)
1871. *LINDSAY, Rt. Hon. Lord. 47 Brook-street, London, W.
1871. ‡Lindsay, Rev. T. M. 7 Great Stuart-street, Edinburgh.
1870. ‡Lindsay, Thomas. 288 Renfrew-street, Glasgow.
1842 *Lingard, John R., F.G.S. Mayfield, Shortlands, by Bromley, Kent.
Lingwood, Robert M., M.A., F.L.S., F.G.S. Cowley House, Exeter.
Lister, James. Liverpool Union Bank, Liverpool.
1870. §Lister, Thomas. Post Office, Barnsley.
Littledale, Harold. Liscard Hall, Cheshire.
1861. *LIVEING, G. D., M.A., F.C.S., Professor of Chemistry in the University of Cambridge. Newnham, Cambridge.
1864. §Livesay, J. G. Cromarty House, Ventnor, Isle of Wight.
1860. ‡Livingstone, Rev. Thomas Gott, Minor Canon of Carlisle Cathedral.
Lloyd, Rev. A. R. Hengold, near Oswestry.
Lloyd, Rev. C., M.A. Whittington, Oswestry.
1842. Lloyd, Edward. King-street, Manchester.
1865. ‡Lloyd, G. B. Wellington-road, Edgbaston, Birmingham.
*Lloyd, George, M.D., F.G.S. Park Glass Works, Birmingham.
1870. §Lloyd, James. 16 Welfield-place, Liverpool.
1870. ‡*Lloyd, J. B.*
1870. ‡Lloyd, J. H., M.D. Anglesea.
*LLOYD, Rev. HUMPHREY, D.D., LL.D., F.R.S. L. & E., M.R.I.A., Provost of Trinity College, Dublin.
1865. ‡Lloyd, John. Queen's College, Birmingham.
Lloyd, Rev. Rees Lewis. Belper, Derbyshire.
1865. *Lloyd, Wilson. Myrod House, Wednesbury.
1854. *LOBLEY, JAMES LOGAN, F.G.S., F.R.G.S. 59 Clarendon-road, Kensington Park, London, W.
1853. *Locke, John. (Care of J. Robertson, Esq., 3 Grafton-street, Dublin.)

Year of
Election.

1867. *Locke, John. 83 Addison-road, Kensington, London, W.
1872. §Locke, John, M.P. 63 Eaton-place, London, S.W.
1863. ‡Lockyer, J. Norman, F.R.S., F.R.A.S. 5 Alexandra-road, Finchley-road, London, N.W.
*Logan, Sir William Edmond, LL.D., F.R.S., F.G.S., F.R.G.S., Director of the Geological Survey of Canada. Montreal, Canada.
1868. ‡Login, Thomas, C.E., F.R.S.E. India.
1862. ‡Long, Andrew, M.A. King's College, Cambridge.
1872. §Long, Jeremiah. 50 Marine Parade, Brighton.
1871. ‡Long, John Jex. 12 Whitevale, Glasgow.
1851. ‡Long, William, F.G.S. Hurts Hall, Saxmundham, Suffolk.
1866. §Longdon, Frederick. Luamdur, near Derby.
1857. ‡Longfield, Rev. George, D.D. 25 Trinity College, Dublin.
Longfield Mountifort, LL.D., M.R.I.A., Regius Professor of Feudal and English Law in the University of Dublin. 47 Fitzwilliam-square, Dublin.
1861. *Longman, William, F.G.S. 36 Hyde-park-square, London, W.
1859. ‡Longmuir, Rev. John, M.A., LL.D. 14 Silver-street, Aberdeen.
Longridge, William S. Oakhurst, Ambergate, Derbyshire.
1871. §Longstaff, George Dixon, M.D., F.C.S. Southfields, Wandsworth, S.W.; and 9 Upper Thames-street, London, E.C.
1872. *Longstaff, Llewellyn Wood, F.R.G.S. Hull.
1861. *Lord, Edward. Adamroyd, Todmorden.
1863. ‡Losh, W. S. Wreay Syke, Carlisle.
1867. *Low, James F. Monifieth, by Dundee.
1863. *Lowe, Lieut.-Colonel Arthur S. H., F.R.A.S. 76 Lancaster-gate, London, W.
1861. *Lowe, Edward Joseph, F.R.S., F.R.A.S., F.L.S., F.G.S., F.M.S. Highfield House Observatory, near Nottingham.
1870. ‡Lowe, G. C. 67 Cecil-street, Greenheys, Manchester.
1868. ‡Lowe, John, M.D. King's Lynn.
1850. ‡Lowe, William Henry, M.D., F.R.S.E. Balgreen, Slateford, Edinburgh.
1853. *Lubbock, Sir John, Bart., M.P., F.R.S., F.L.S., F.G.S. High Elms Farnborough, Kent.
1870. ‡Lubbock, Montague. High Elms, Farnborough, Kent.
1849. *Luckcock, Howard. Oak-hill, Edgbaston, Birmingham.
1867. *Luis, John Henry. Cidhmore, Dundee.
1866. *Lund, Charles. Market-street, Bradford.
1850. *Lundie, Cornelius. Tweed Lodge, Cardiff.
1853. ‡Lunn, William Joseph, M.D. 23 Charlotte-street, Hull.
1858. *Lupton, Arthur. Headingley, near Leeds.
1864. *Lupton, Darnton, Jun. The Harehills, Leeds.
1864. *Lutley, John. Brockhampton Park, Worcester.
1866. §Lycett, Sir Francis. 18 Highbury-grove, London, N.
*Lyell, Sir Charles, Bart., M.A., LL.D., D.C.L., F.R.S., F.L.S. V.P.G.S., Hon. M.R.S.Ed. 73 Harley-street, London, W.
1871. ‡Lyell, Leonard. 42 Regent's Park-road, London, N.W.
1857. ‡Lyons, Robert D. 31 Upper Merrion-street, Dublin.
1862. *Lyte, Maxwell F., F.C.S. Bagnères de Bigorre, France.
1849. ‡Lyttleton, The Right Hon. Lord, D.C.L., F.R.S. 12 Stratton-street, London, W.

1852. ‡MacAdam, Robert. 18 College-square East, Belfast.
1854. *Macadam, Stevenson, Ph.D., F.R.S.E., F.C.S., Lecturer on Chemistry. Surgeons' Hall, Edinburgh; and Brighton House, Portobello, by Edinburgh.

Year of Election.

1868. ‡MACALISTER, ALEXANDER, M.D., Professor of Zoology in the University of Dublin. 13 Adelaide-road, Dublin.
1868. ‡M'Allan, W. A. Norwich.
*M'ANDREW, ROBERT, F.R.S., F.L.S. Isleworth House, Isleworth, Middlesex.
1866. *M'Arthur, A. Raleigh Hall, Brixton Rise, London, S.W.
1840. Macaulay, James, M.D. 22 Cambridge-road, Kilburne, London, N.W.
1871. ‡M'Bain, James, M.D., R.N. Logie Villa, York-road, Trinity, Edinburgh.
*MacBrayne, Robert. Househill Hamlet, Glasgow.
1866. ‡M'CALLAN, Rev. J. F., M.A. Basford, near Nottingham.
1855. ‡M'Callum, Archibald K., M.A. Whitehall-terrace, Glasgow.
1863. ‡M'Calmont, Robert. Gatton Park, Reigate.
1855. ‡M'Cann, James, F.G.S. Holmfirth, Yorkshire.
1857. ‡M'Causland, Dominick. 12 Fitzgibbon-street, Dublin.
1865. *M'CLEAN, JOHN ROBINSON, F.R.S., F.G.S. 2 Park-street, Westminster, S.W.
1840. M'Clelland, James, F.S.S. 32 Pembridge-square, London, W.
1868. ‡M'CLINTOCK, Captain Sir FRANCIS L., R.N., F.R.S., F.R.G.S. United Service Club, Pall Mall, London, S.W.
1872. *McClure, J. H. Manchester.
*M'Connel, James. Moore-place, Esher, Surrey.
1859. *M'Connell, David C., F.G.S. 44 Manor-place, Edinburgh.
1858. ‡M'Connell, J. E. Woodlands, Great Missenden.
MACDONALD, WILLIAM, M.D., F.R.S.E., F.L.S., F.G.S., Professor of Civil and Natural History. St. Andrews, N.B.
1871. §M'Donald, William. Yopohama, Japan. (Care of R. K. Knenitt, Esq., Sun-court, Cornhill, E.C.)
MacDonnell, Hercules H. G. 2 Kildare-place, Dublin.
*M'Ewan, John. 13 Hamilton-terrace West, Partick, by Glasgow.
1859. ‡Macfarlane, Alexander. 73 Bon Accord-street, Aberdeen.
1871. §M'Farlane, Donald. The College Laboratory, Glasgow.
1855. ‡M'Farlane, Walter. Saracen Foundry, Glasgow.
1854. *MACFIE, ROBERT ANDREW, M.P. 13 Victoria-street, Westminster, S.W.
1867. *M'Gavin, Robert. Ballumbie, Dundee.
1852. *M'GEE, WILLIAM, M.D. 10 College-square North, Belfast.
1855. ‡MacGeorge, Andrew, jun. 21 St. Vincent-place, Glasgow.
1872. §McGeorge, Mungo. Nithodale, Laurie-park, Sydenham.
1855. ‡M'Gregor, Alexander Bennett. 19 Woodside-crescent, Glasgow.
1855. ‡MacGregor, James Watt. Wallace-grove, Glasgow.
1859. ‡M'Hardy, David. 54 Netherkinkgate, Aberdeen.
1859. ‡Macintosh, John. Middlefield House, Woodside, Aberdeen.
1867. *M'INTOSH, W. C., M.D., F.L.S. Murthly, Perthshire.
1854. *MacIver, Charles. Water-street, Liverpool.
1871. §Mackay, Rev. Dr. A., F.R.G.S. Oakland Villa, Hatton-place, Edinburgh.
1865. ‡Mackeson, Henry B., F.G.S. Hyde, Kent.
1865. ‡Mackintosh, Daniel, F.G.S. Chichester.
1855. ‡M'Kenzie, Alexander. 89 Buchanan-street, Glasgow.
*Mackenzie, James. Glentore, by Glasgow.
1865. ‡*Mackenzie, Kenneth Robert Henderson, F.S.A., F.A.S.L.*
1867. §MACKIE, SAMUEL JOSEPH, F.G.S. 84 Kensington-park-road, London, W.
*Mackinlay, David. Great Western-terrace, Hillhead, Glasgow.
1872. §Mackey, J. A. 24 Buckingham-place, Brighton.

Year of Election.

1867. §Mackson, H. G. 25 Cliff-road, Woodhouse, Leeds.
1872. *MacLachlan, Robert, F.L.S. 39 Limes-grove, Lewisham.
1860. ‡Maclaren, Archibald. Summertown, Oxfordshire.
1864. §MACLAREN, DUNCAN, M.P. Newington House, Edinburgh.
1859. ‡MACLEAR, Sir THOMAS, F.R.S., F.R.G.S., F.R.A.S., late Astronomer Royal at the Cape of Good Hope. Cape Town, South Africa.
1862. ‡Macleod, Henry Dunning. 17 Gloucester-terrace, Camden-hill-road, London, W.
1868. §M'LEOD, HERBERT, F.C.S. Indian Civil Engineering College, Cooper's Hill, Egham.
1861. *Maclure, John William. 2 Bond-street, Manchester.
1862. ‡Macmillan, Alexander. Streatham-lane, Upper Tooting, Surrey.
1871. ‡M'Nab, William Ramsay, M.D. Royal Agricultural College, Cirencester.
1870. ‡Macnaught, John, M.D. 74 Huskisson-street, Liverpool.
1867. §M'Neill, John. Balhousie House, Perth.
MACNEILL, The Right Hon. Sir John, G.C.B., F.R.S.E., F.R.G.S. Granton House, Edinburgh.
MACNEILL, Sir John, LL.D., F.R.S., M.R.I.A. 17 The Grove, South Kensington, London, S.W.
1850. ‡Macnight, Alexander. 12 London-street, Edinburgh.
1859. ‡Macpherson, Rev. W. Kilmuir Easter, Scotland.
Macredie, P. B. Mure, F.R.S.E. Irvine, Ayrshire.
1852. *Macrory, Adam John. Duncairn, Belfast.
*MACRORY, EDMUND, M.A. 40 Leinster-square, Bayswater, London, W.
1855. ‡M'Tyre, William, M.D. Maybole, Ayrshire.
1855. ‡MACVICAR, Rev. JOHN GIBSON, D.D., LL.D. Moffat, N.B.
1868. ‡Magnay, F. A. Drayton, near Norwich.
Magor, J. B. Redruth, Cornwall.
1869. §MAIN, Rev. R., F.R.S., F.R.A.S., Director of the Radcliffe Observatory, Oxford.
1869. ‡Main, Robert. Admiralty, Somerset House, W.C.
1866. §MAJOR, RICHARD H., F.S.A., F.R.G.S. British Museum, London, W.C.
*MALAHIDE, TALBOT DE, The Right Hon. Lord, M.A., F.R.S., F.G.S., F.S.A. Malahide Castle, Co. Dublin.
*Malcolm, Frederick. Mordon College, Blackheath, London, S.E.
1870. *Malcolm, Sir James, Bart. The Priory, St. Michael's Hamlet, Aigburth, Liverpool.
1863. ‡Maling, C. T. Lovaine-crescent, Newcastle-on-Tyne.
*MALLET, ROBERT, Ph.D., F.R.S., F.G.S., M.R.I.A. The Grove, Clapham-road, Clapham; and 7 Westminster-chambers, Victoria-street, London, S.W.
1857. ‡Mallet, Dr. John William, F.C.S., Professor of Chemistry in the University of Virginia, U. S.
1846. ‡MANBY, CHARLES, F.R.S., F.G.S. 60 Westbourne-terrace, Hyde Park, London, W.
1866. §MANN, ROBERT JAMES, M.D., F.R.A.S. 5 Kingsdown-villas, Wandsworth Common, S.W.
Manning, The Right Rev. H.
1866. ‡Manning, John. Waverley-street, Nottingham.
1870. ‡Manifold, W. H. 45 Rodney-street, Liverpool.
1864. ‡Mansel, J. C. Long Thorns, Blandford.
1865. ‡March, J. F. Fairfield House, Warrington.
1870. ‡Marcoartu, Senor Don Arturo de. Madrid.
1864. ‡MARKHAM, CLEMENTS R., C.B., F.L.S., F.R.G.S. 21 Eccleston-square, Pimlico, London, S.W.

Year of Election.

1863. ‡Marley, John. Mining Office, Darlington.
*Marling, Samuel S., M.P. Stanley Park, Stroud, Gloucestershire.
1871. §Marreco, A. Friere-. Physical College of Science, Newcastle-on-Tyne.
Marriott, John. Allerton, Liverpool.
1857. §Marriott, William, F.C.S. Grafton-place, Huddersfield.
1842. Marsden, Richard. Norfolk-street, Manchester.
1866. ‡Marsh, Dr. J. C. L. Park-row, Nottingham.
1870. ‡Marsh, John. Rann Lea, Rainhill, Liverpool.
1856. ‡Marsh, M. H. Wilbury Park, Wilts.
1864. ‡Marsh, Thomas Edward Miller. 37 Grosvenor-place, Bath.
Marshall, James. Headingly, near Leeds.
1852. ‡Marshall, James D. Holywood, Belfast.
1858. ‡Marshall, Reginald Dykes. Adel, near Leeds.
*Marshall, James Garth, M.A., F.G.S. Headlingley House, Leeds.
1849. *Marshall, William P. 6 Portland-road, Edgbaston, Birmingham.
1865. §Marten, Edward Bindon. Pedmore, near Stourbridge.
1848. ‡Martin, Henry D. 4 Imperial Circus, Cheltenham.
1871. ‡Martin, Rev. Hugh, M.A. Greenhill-cottage, Lasswade by Edinburgh.
1870. ‡Martin, Robert, M.D. 120 Upper Brook-street, Manchester.
1836. Martin, Studley. 177 Bedford-street South, Liverpool.
1867. *Martin, William, Jun. Leafield-place, Dundee.
**Martindale, Nicholas.*
*Martineau, Rev. James. 10 Gordon-street, Gordon-square, London, W.C.
1865. ‡Martineau, R. F. Highfield-road, Edgbaston, Birmingham.
1865. ‡Martineau, Thomas. 7 Cannon-street, Birmingham.
1847. ‡Maskelyne, Nevil Story, M.A., F.R.S., F.G.S., Keeper of the Mineralogical Department, British Museum. 112 Gloucester-terrace, Hyde Park Gardens, London, W.
1861. *Mason, Hugh. Groby Lodge, Ashton-under-Lyne.
1868. §Mason, James Wood, F.G.S. The Indian Museum, Calcutta. (Care of Henry S. King & Co., 65 Cornhill, London, E.C.)
Massey, Hugh, Lord. Hermitage, Castleconnel, Co. Limerick.
1870. ‡Massey, Thomas. 5 Gray's-Inn-square, London, W.C.
1870. ‡Massy, Frederick. 50 Grove-street, Liverpool.
1865. *Mathews, G. S. Portland-road, Edgbaston, Birmingham.
1861. *Mathews, William, jun., M.A., F.G.S. 49 Harborne-road, Birmingham.
1859. ‡Matthew, Alexander C. 3 Canal-terrace, Aberdeen.
1865. ‡Matthews, C. E. Waterloo-street, Birmingham.
1858. ‡Matthews, F. C. Mandre Works, Driffield, Yorkshire.
*Matthews, Henry, F.C.S. 60 Gower-street, London, W.C.
1860. §Matthews, Rev. Richard Brown. Shalford Vicarage, near Guildford.
1863. ‡Maughan, Rev. W. Benwell Parsonage, Newcastle-on-Tyne.
1855. ‡Maule, Rev. Thomas, M.A. Partick, near Glasgow.
1865. *Maw, George, F.L.S., F.G.S., F.S.A. Benthall Hall, Broseley, Shropshire.
1864. *Maxwell, Francis. Speddock, near Dumfries.
*Maxwell, James Clerk, M.A., LL.D., F.R.S. L. & E. Professor of Experimental Physics in the University of Cambridge. Glenlair, Dalbeattie, N.B.; and 11 Scroope-terrace, Cambridge.
*Maxwell, Robert Perceval. Groomsport House, Belfast.
1865. *May, Walter. Elmley Lodge, Harborne, Birmingham.
1868. §Mayall, J. E., F.C.S. Hove-place House, Brighton.
*Mayne, Rev. Charles, M.R.I.A. Killaloe, Co. Clare, Ireland.

Year of
Election.

1863. §Mease, George D. Bylton Villa, South Shields.
1863. ‡Mease, Solomon. Cleveland House, North Shields.
‡Meath, Samuel Butcher, D.D., Lord Bishop of. Ardbraccan, Co. Meath.
1871. ‡Meikie, James, F.S.S. 6 St. Andrew's-square, Edinburgh.
1867. ‡Meldrum, Charles. Mauritius.
1866. ‡Mello, Rev. J. M. St. Thomas's Rectory, Brampton, Chesterfield.
1854. ‡Melly, Charles Pierre. 11 Rumford-street, Liverpool.
1847. ‡Melville, Professor Alexander Gordon, M.D. Queen's College, Galway.
1863. ‡Melvin, Alexander. 42 Buccleuch-place, Edinburgh.
1862. §MENNELL, HENRY J. St. Dunstan's-buildings, Great Tower-street, London, E.C.
1868. §MERRIFIELD, CHARLES W., F.R.S., Principal of the Royal School of Naval Architecture, Superintendent of the Naval Museum at South Kensington, Hon. Sec. I.N.A. 23 Scarsdale-villas, Kensington, London, S.W.
1872. §Merryweather, Richard M. Clapham House, Clapham Common, London, S.W.
1871. §Merson, John. Northumberland County Asylum, Morpeth.
1872. *Messent, John. 429 Strand, London, W.C.
1863. ‡Messent, P. T. 4 Northumberland-terrace, Tynemouth.
1869. §MIALL, LOUIS C. Philosophical Hall, Leeds
1847. *Michell, Rev. Richard, D.D., Principal of Magdalen Hall, Oxford.
1865. ‡Michie, Alexander. 26 Austin Friars, London, E.C.
1865. ‡Middlemore, William. Edgbaston, Birmingham.
1866. ‡Midgley, John. Colne, Lancashire.
1867. ‡Midgley, Robert. Colne, Lancashire.
1859. ‡Millar, John. Lisburn, Ireland.
1863. §Millar, John, M.D., F.L.S., F.G.S. Bethnal House, Cambridge-road, London, N.E.
Millar, Thomas, M.A., LL.D., F.R.S.E. Perth.
1865. ‡Miller, Rev. Canon J. C., D.D. The Vicarage, Greenwich, London, S.E.
1861. *Miller, Robert. Broomfield House, Reddish, near Manchester.
MILLER, WILLIAM HALLOWS, M.A., LL.D., For. Sec. R.S., F.G.S., Professor of Mineralogy in the University of Cambridge. 7 Scroope-terrace, Cambridge.
1868. *Milligan, Joseph, F.L.S., F.G.S., F.R.A.S., F.R.G.S.. 15 Northumberland-street, Strand, London, W.C.
1842. Milligan, Robert. Acacia in Randon, Leeds.
1868. §MILLS, EDMUND J., D.Sc. 12 Pemberton-terrace, St. John's-park, London, N.
*Mills, John Robert. Bootham, York.
1867. ‡Milne, James. Murie House, Errol, by Dundee.
Milne, Admiral Sir Alexander, G.C.B., F.R.S.E. 65 Rutland-gate, London, S.W.
*MILNE-HOME, DAVID, M.A., F.R.S.E., F.G.S. Paxton House, Berwick, N.B.
1854. *Milner, William. 50 Bentley-road, Liverpool.
1864. *MILTON, The Right Hon. Lord, F.R.G.S. 17 Grosvenor-street, London, W.; and Wentworth, Yorkshire.
1865. ‡Minton, Samuel, F.G.S. Oakham House, near Dudley.
1855. ‡Mirrlees, James Buchanan. 45 Scotland-street, Glasgow.
1859. ‡Mitchell, Alexander, M.D. Old Rain, Aberdeen.
1863. ‡Mitchell, C. Walker. Newcastle-on-Tyne.
1870. §Mitchell, John. York House, Clitheroe, Lancashire.

Year of Election.

1868. §Mitchell, John, jun. Pole Park House, Dundee.
1862. *MITCHELL, WILLIAM STEPHEN, LL.B., F.L.S., F.G.S. Caius College, Cambridge.
1855. *Moffat, John, C.E. Ardrossan, Scotland.
1854. §MOFFAT, THOMAS, M.D., F.G.S., F.R.A.S., F.M.S. Hawarden, Chester.
1864. †Mogg, John Rees. High Littleton House, near Bristol.
1866. §MOGGRIDGE, MATTHEW, F.G.S. Ditton Lodge, Thames Ditton, Surrey.
1855. §Moir, James. 174 Gallogate, Glasgow.
1861. ‡Molesworth, Rev. W. N., M.A. Spotland, Rochdale.
Mollan, John, M.D. 8 Fitzwilliam-square North, Dublin.
1852. ‡Molony, William, LL.D. Carrickfergus.
1865. §MOLYNEAUX, WILLIAM, F.G.S. Manor House, Burton-upon-Trent.
1860. §Monk, Rev. William, M.A., F.R.A.S. Wymington Rectory, Higham Ferrers, Northamptonshire.
1853. ‡Monroe, Henry, M.D. 10 North-street, Sculcoates, Hull.
1872. §Montgomery, R. Mortimer. 3 Porchester-place, Edgeware-road, London, W.
1872. §Moon, W., LL.D. 104 Queen's-road, Brighton.
1857. ‡Moore, Arthur. Cradley House. Clifton, Bristol.
1859. §MOORE, CHARLES, F.G.S. 6 Cambridge-terrace, Bath.
1857. ‡Moore, Rev. John, D.D. Clontarf, Dublin.
Moore, John. 2 Meridian-place, Clifton, Bristol.
*MOORE, JOHN CARRICK, M.A., F.R.S., F.G.S. 113 Eaton-street, London, S.W.; and Corswall, Wigtonshire.
1866. *MOORE, THOMAS, F.L.S. Botanic Gardens, Chelsea, London, S.W.
1854. ‡MOORE, THOMAS JOHN, Cor. M.Z.S. Free Public Museum, Liverpool.
1857. *Moore, Rev. William Prior. The Royal School, Cavan, Ireland.
1871. §MORE, ALEXANDER, F.L.S., M.R.I.A. 3 Botanic View, Glasnevin, Dublin.
1868. †Morgan, Thomas H. Oakhurst, Hastings.
1833. Morgan, William. Uckfield, Sussex.
Morley, George. Park-place, Leeds.
1863. ‡MORLEY, SAMUEL, M.P. Lenton-grove, Nottingham.
1865. *Morrieson, Colonel Robert. Oriental Club, Hanover-square, London, W.
*Morris, Rev. Francis Orpen, B.A. Nunburnholme Rectory, Hayton, York.
Morris, Samuel, M.R.D.S. Fortview, Clontarf, near Dublin.
1861. ‡Morris, William. The Grange, Salford.
1871. *Morrison, James Darsie. 27 Grange-road, Edinburgh.
1867. ‡Morrison, William R. Dundee.
1863. ‡Morrow, R. J. Bentick-villas, Newcastle-on-Tyne.
1865. §Mortimer, J. R. St. John's-villas, Driffield.
1869. †Mortimer, William. Bedford-circus, Exeter.
1857. §MORTON, GEORGE H., F.G.S. 21 West Derby-street, Liverpool.
1858. *MORTON, HENRY JOSEPH. Garforth House, West Garforth, near Leeds.
1871. §Morton, Hugh. Belvedere House, Trinity, Edinburgh.
1868. ‡Moseley, H. N. Olveston, Bristol.
1857. ‡Moses, Marcus. 4 Westmoreland-street, Dublin.
Mosley, Sir Oswald, Bart., D.C.L. Rolleston Hall, Burton-upon-Trent, Staffordshire.

Year of Election.

Moss, John. Otterspool, near Liverpool.
1870. §Moss, John Miles, M.A. 2 Esplanade, Waterloo, Liverpool.
1853. *Moss, William Henry. Kingston-terrace, Hull.
1864. *Mosse, J. R. Public Works' Department, Ceylon. (Care of H. S. King & Co., 65 Cornhill, London, E.C.)
1869. §MOTT, ALBERT J. Claremont House, Seaforth, Liverpool.
1865. §Mott, Charles Grey. The Park, Birkenhead.
1866. §Mott, Frederick T., F.R.G.S. 1 De Montfort-street, Leicester.
1872. §Mott, Miss Minnie. 1 De Montfort-street, Leicester.
1862. *MOUAT, FREDERICK JOHN, M.D., late Inspector-General of Prisons, Bengal. 12 Durham-villas, Campden-hill, London, W.
1856. ‡Mould, Rev. J. G., B.D. 21 Camden-crescent, Bath.
1863. ‡Mounsey, Edward. Sunderland.
Mounsey, John. Sunderland.
1861. *Mountcastle, William Robert. 7 Market-street, Manchester.
Mowbray, James. Combus, Clackmannan, Scotland.
1850. ‡Mowbray, John T. 15 Albany-street, Edinburgh.
1871. §Muir, W. Hamilton. Toravon, Stirlingshire.
1872. §Muirhead, Alexander, D.Sc. 159 Camden-road, London, N.
1871. *Muirhead, Henry, M.D. Bushey-hill, Cambuslang, Lanarkshire.
Muirhead, James. 90 Buchanan-street, Glasgow.
1857. ‡Mullins, M. Bernard, M.A., C.E. 1 Fitzwilliam-square South, Dublin.
Munby, Arthur Joseph. 6 Fig-tree-court, Temple, London, E.C.
1866. ‡MUNDELLA, A. J., M.P., F.R.G.S. The Park, Nottingham.
1864. *MUNRO, Major-General WILLIAM, C.B., F.L.S. United Service Club, Pall Mall, London, S.W.; and Mapperton Lodge, Farnborough, Hants.
1872. *Munster, H. Selwood Lodge, Brighton.
1872. *Munster, William Felix. Selwood Lodge, Brighton.
1864. §MURCH, JEROM. Cranwells, Bath.
*Murchison, John Henry. Surbiton-hill, Kingston, Surrey.
1864. *Murchison, K. R. 24 Chapel-street, Park-lane, London, W.
1855. †Murdock, James B. Hamilton-place, Langside, Glasgow.
1858. ‡Murgatroyd, William. Bank Field, Bingley.
1852. ‡Murney, Henry, M.D. 10 Chichester-street, Belfast.
1852. ‡Murphy, Joseph John. Old Forge, Dunmurry, Co. Antrim.
1869. §Murray, Adam. 4 Westbourne-crescent, Hyde Park, London, W.
1850. ‡MURRAY, ANDREW, F.L.S. 67 Bedford-gardens, Kensington, London, W.
1871. ‡Murray, Captain, R.N. Murrathwaite, Ecclefachan, Scotland.
1871. §Murray, Dr. Ivor, F.R.S.E. The Knowle, Brenchley, Staplehurst, Kent.
Murray, John, F.G.S., F.R.G.S. 50 Albemarle-street, London, W.; and Newsted, Wimbledon, Surrey.
1871. §Murray, John. 3 Clarendon-crescent, Edinburgh.
1859. ‡Murray, John, M.D. Forres, Scotland.
*Murray, John, C.E. 11 Great Queen-street, Westminster, S.W.
‡Murray, Rev. John. Morton, near Thornhill, Dumfriesshire.
1872. §Murray, J. Jardine. 99 Montpellier-road, Brighton.
1863. ‡Murray, William. 34 Clayton-street, Newcastle-on-Tyne.
1859. *Murton, James. Silverdale, near Carnforth, Lancaster.
Musgrave, The Venerable Charles, D.D., Archdeacon of Craven, Halifax.
1861. ‡Musgrove, John, jun. Bolton.
1870. *Muspratt, Edward Knowles. Seaforth Hall, near Liverpool.
1865. ‡Myers, Rev. E., F.G.S. 3 Waterloo-road, Wolverhampton.

Year of Election.

1859. §MYLNE, ROBERT WILLIAM, F.R.S., F.G.S., F.S.A. 21 Whitehall-place, London, S.W.

1850. †Nachot, H. W., Ph.D. 73 Queen-street, Edinburgh.
1842. Nadin, Joseph. Manchester.
1855. *NAPIER, JAMES R., F.R.S. 22 Blythwood-square, Glasgow.
1839. *NAPIER, Right Hon. Sir JOSEPH, Bart. 4 Merrion-square, Dublin.
*Napier, Captain Johnstone. Tavistock House, Salisbury.
1855. †Napier, Robert. West Chandon, Gareloch, Glasgow.
Napper, James William L. Loughcrew, Oldcastle., Co. Meath.
1872. §Nares, Capt. G. S., R.N. Grant's Bank, Portsmouth.
1866. †Nash, Davyd W., F.S.A., F.L.S. 10 Imperial-square, Cheltenham.
1850. *NASMYTH, JAMES. Penshurst, Tunbridge.
1864. †Natal, William Colenso, Lord Bishop of.
1860. †Neate, Charles, M.A. Oriel College, Oxford.
1867. §NEAVES, The Right Hon. Lord. 7 Charlotte-square, Edinburgh.
1853. †Neill, William, Governor of Hull Jail. Hull.
1855. †Neilson, Walter. 172 West George-street, Glasgow.
1865. †Neilson, W. Montgomerie. Glasgow.
Ness, John. Helmsley, near York.
1868. †Nevill, Rev. H. R. Great Yarmouth.
1866. *Nevill, Rev. Samuel Tarratt, B.A., F.L.S. Shelton Rectory, near Stoke-upon-Trent.
1857. †Neville, John, C.E., M.R.I.A. Dundalk, Ireland.
1852. †Neville, Parke, C.E. Town Hall, Dublin.
1869. †Nevins, John Birkbeck, M.D. 3 Abercromby-square, Liverpool.
1842. New, Herbert. Evesham, Worcestershire.
Newall, Henry. Hare-hill, Littleborough, Lancashire.
*Newall, Robert Stirling. Ferndene, Gateshead-upon-Tyne.
1866. *Newdegate, Albert L. 10 Esplanade, Dover.
1842. *NEWMAN, Professor FRANCIS WILLIAM. Norwood-villa, Arundel-crescent, Weston-super-Mere.
*Newman, William. Darley Hall, near Barnsley, Yorkshire.
1863. *NEWMARCH, WILLIAM, F.R.S. Beech Holme, Clapham Common, London, S.W.
1866. *Newmarch, William Thomas. 8 Lovain-crescent, Newcastle-upon-Tyne.
1860. *NEWTON, ALFRED, M.A., F.R.S., F.L.S., Professor of Zoology and Comparative Anatomy in the University of Cambridge. Magdalen College, Cambridge.
1872. §Newton, Rev. J. 125 Eastern-road, Brighton.
1865. †Newton, Thomas Henry Goodwin. Clopton House, near Stratford-on-Avon.
1867. †Nicholl, Dean of Guild. Dundee.
Nicholl, Iltyd, F.L.S. Uske, Monmouthshire.
1866. §NICHOLSON, Sir CHARLES, Bart., D.C.L., LL.D., M.D., F.G.S., F.R.G.S. 26 Devonshire-place, Portland-place, London, W.
1838. *Nicholson, Cornelius, F.G.S., F.S.A. Welfield, Muswell-hill, London, N.
1861. *Nicholson, Edward. 88 Mosley-street, Manchester.
1871. §Nicholson, E. Chambers. Herne-hill, London, S.E.
1867. †NICHOLSON, HENRY ALLEYNE, M.D., D.Sc., F.G.S., Professor of Natural History, University College, Toronto, Canada.
*Nicholson, John A., A.M., M.B., Lic. Med., M.R.I.A. Balrath Burry, Kells, Co. Meath.
1850. †NICOL, JAMES, F.R.S.E., F.G.S., Professor of Natural History in Marischal College, Aberdeen.

Year of Election.

1867. ‡Nimmo, Dr. Matthew, L.R.C.S.E. Nethergate, Dundee.
Niven, Ninian. Clonturk Lodge, Drumcondra, Dublin.
1864. ‡Noad, Henry M., Ph.D., F.R.S., F.C.S. 72 Hereford-road, Bayswater, London, W.
1863. *Noble, Captain. Elswick Works, Newcastle-on-Tyne.
1870. ‡Nolan, Joseph. 14 Hume-street, Dublin.
1860. *Nolloth, Matthew S., Captain R.N., F.R.G.S. United Service Club, S.W.; and 13 North-terrace, Camberwell, London, S.E.
1859. ‡Norfolk, Richard. Messrs. W. Rutherford and Co., 14 Canada Dock, Liverpool.
1868. ‡Norgate, William. Newmarket-road, Norwich.
1863. §Norman, Rev. Alfred Merle, M.A. Burnmoor Rectory, Fence House, Co. Durham.
Norreys, Sir Denham Jephson, Bart. Mallow Castle, Co. Cork.
Norris, Charles. St. John's House, Halifax.
1865. ‡Norris, Richard, M.D. 2 Walsall-road, Birchfield, Birmingham.
1872. §Norris, Thomas George. Corphwysfa, Swansea.
1866. ‡North, Thomas. Cinder-hill, Nottingham.
Northampton, Charles Douglas, The Right Hon. Marquis of. 145 Piccadilly, London, W.; and Castle Ashby, Northamptonshire.
1869. ‡Northcote, Right Hon. Sir Stafford H., Bart., C.B., M.P. Pynes, Exeter; and 86 Harley-street, London, W.
*Northwick, The Right Hon. Lord, M.A. 7 Park-street, Grosvenor-square, London, W.
1868. ‡Norwich, The Hon. and Right Rev. J. T. Pelham, D.D., Lord Bishop of. Norwich.
1861. ‡Noton, Thomas. Priory House, Oldham.
Nowell, John. Farnley Wood, near Huddersfield.
1869. §Noyes, H. C. Victoria-terrace, Heavitree, Exeter.

O'Beirne, James, M.D.
O'Brien, Baron Lucius. Dromoland, Newmarket-on-Fergus, Ireland.
O'Callaghan, George. Tallas, Co. Clare.
1858. *O'Callaghan, Patrick, LL.D., D.C.L. 16 Clarendon-square, Leamington.
Odgers, Rev. William James. Sion-hill, Bath.
1858. *Odling, William, M.B., F.R.S., F.C.S., Waynflete Professor of Chemistry in the University of Oxford. Museum, Oxford.
1857. ‡O'Donnavan, William John. Portarlington, Ireland.
1870. ‡O'Donnell, J. O., M.D. 34 Rodney-street, Liverpool.
1866. ‡Ogden, James. Woodhouse, Loughborough.
1859. ‡Ogilvie, C. W. Norman. Baldovan House, Dundee.
*Ogilvie, George, M.D., Professor of the Institutes of Medicine in Marischal College, Aberdeen. 29 Union-place, Aberdeen.
1863. ‡Ogilvy, G. R. Inverquharity, N.B.
1863. ‡Ogilvy, Sir John, Bart., M.P. Inverquharity, N.B.
*Ogle, William, M.D., M.A. 98 Friar-gate, Derby.
1859. ‡Ogston, Francis, M.D. 18 Adelphi-court, Aberdeen.
1837. ‡O'Hagan, John. 20 Kildare-street, Dublin.
1862. ‡O'Kelly, Joseph, M.A. 51 Stephen's-green, Dublin.
1857. ‡O'Kelly, Matthias J. Dalkey, Ireland.
1853. §Oldham, James, C.E. Austrian-chambers, Hull.
1857. *Oldham, Thomas, M.A., LL.D., F.R.S., F.G.S., M.R.I.A., Director of the Geological Survey of India. 1 Hastings-street, Calcutta.
1860. ‡O'Leary, Professor Purcell, M.A. Sydney-place, Cork.
1863. ‡Oliver, Daniel, F.R.S., Professor of Botany in University College, London. Royal Gardens, Kew.

Year of Election.

*OMMANNEY, ERASMUS, Vice-Admiral, C.B., F.R.S., F.R.A.S., F.R.G.S. 6 Talbot-square, Hyde Park, London, W.; and United Service Club, Pall Mall, London, S.W.
1872. §Onslow, D. Robert. New University Club, St. James's, London, S.W.
1867. ‡Orchar, James G. 9 William-street, Forebank, Dundee.
1842. ORMEROD, GEORGE WAREING, M.A., F.G.S. Brookbank, Teignmouth.
1861. ‡Ormerod, Henry Mere. Clarence-street, Manchester; and 11 Woodland-terrace, Cheetham-hill, Manchester.
1858. †Ormerod, T. T. Brighouse, near Halifax.
ORPEN, JOHN H., LL.D., M.R.I.A. 58 Stephen's-green, Dublin.
1854. †Orr, Sir Andrew. Blythwood-square, Glasgow.
1865. ‡Osborne, E. C. Carpenter-road, Edgbaston, Birmingham.
*OSLER, A. FOLLETT, F.R.S. South Bank, Edgbaston, Birmingham.
1865. *Osler, Henry F. 50 Carpenter-road, Edgbaston, Birmingham.
1869. *Osler, Sidney F. South Bank, Edgbaston, Birmingham.
1854. §Outram, Thomas. Greetland, near Halifax.
OVERSTONE, SAMUEL JONES LLOYD, LORD, F.G.S. 2 Carlton-gardens, London, S.W.; and Wickham Park, Bromley.
1870. ‡Owen, Harold. The Brook Villa, Liverpool.
1857. ‡Owen, James H. Park House, Sandymount, Co. Dublin.
OWEN, RICHARD, M.D., D.C.L., LL.D., F.R.S., F.L.S., F.G.S., Hon. M.R.S.E., Director of the Natural-History Department, British Museum. Sheen Lodge, Mortlake, Surrey, S.W.
1863. *Ower, Charles, C.E. 11 Craigie-terrace, Dundee.

1859. ‡PAGE, DAVID, LL.D., F.R.S.E., F.G.S. College of Physical Science, Newcastle-upon-Tyne.
1863. ‡Paget, Charles. Ruddington Grange, near Nottingham.
1872. *Paget, Joseph. Stuffynwood Hall, Mansfield, Notts.
1870. ‡Palgrave, R. H. Inglis. 11 Britannia-terrace, Great Yarmouth.
1866. §Palmer, H. 76 Goldsmith-street, Nottingham.
1866. §Palmer, William. Iron Foundry, Canal-street, Nottingham.
1872. *Palmer, W. R. Phœnix Lodge, Brixton, London, S.W.
Palmes, Rev. William Lindsay, M.A. The Vicarage, Hornsea, Hull.
1857. *Parker, Alexander, M.R.I.A.. 59 William-street, Dublin.
1863. †Parker, Henry. Low Elswick, Newcastle-on-Tyne.
1863. ‡Parker, Rev. Henry. Idlerton Rectory, Low Elswick, Newcastle-on-Tyne.
Parker, Joseph, F.G.S. Upton Chaney, Bitton, near Bristol.
Parker, Richard. Dunscombe, Cork.
Parker, Rev. William. Saham, Norfolk.
1865. *Parker, Walter Mantel. High-street, Alton, Hants.
1853. ‡Parker, William. Thornton-le-Moor, Lincolnshire.
1865. *Parkes, Samuel Hickling. King's Norton, Worcestershire.
1864. §PARKES, WILLIAM. 23 Abingdon-street, Westminster, S.W.
1859. †Parkinson, Robert, Ph.D. Bradford, Yorkshire.
1863. ‡Parland, Captain. Stokes Hall, Jesmond, Newcastle-on-Tyne.
1862. *Parnell, John, M.A. Hadham House, Upper Clapton, London, N.E.
Parnell, Richard, M.D., F.R.S.E. Gattonside Villa, Melrose, N.B.
1865. *Parsons, Charles Thomas. 8 Portland-road, Edgbaston, Birmingham.
1855. †Paterson, William. 100 Brunswick-street, Glasgow.
1861. ‡Patterson, Andrew. Deaf and Dumb School, Old Trafford, Manchester.
1871. *Patterson, A. H. Craigdarragh, Belfast.

Year of Election.

1863. ‡Patterson, H. L. Scott's House, near Newcastle-on-Tyne.
1867. ‡Patterson, James. Kinnettles, Dundee.
1871. ‡Patterson, John.
1863. ‡Pattinson, John. 75 The Side, Newcastle-on-Tyne.
1863. ‡Pattinson, William. Felling, near Newcastle-on-Tyne.
1867. ‡Pattison, Samuel R., F.G.S. 50 Lombard-street, London, E.C.
1864. ‡Pattison, Dr. T. H. London-street, Edinburgh.
1863. §PAUL, BENJAMIN H., Ph.D. 1 Victoria-street, Westminster, S.W.
1863. ‡PAVY, FREDERICK WILLIAM, M.D., F.R.S., Lecturer on Physiology and Comparative Anatomy and Zoology at Guy's Hospital. 35 Grosvenor-street, London, W.
1864. ‡Payne, Edward Turner. 3 Sydney-place, Bath.
1851. ‡Payne, Joseph. 4 Kildare-gardens, Bayswater, London, W.
1866. §Payne, Dr. Joseph F. 4 Kildare-gardens, Bayswater, London, W.
1847. §PEACH, CHARLES W., Pres. R.P.S. Edin., A.L.S. 30 Haddington-place, Leith-walk, Edinburgh.
1868. ‡Peacock, Ebenezer. 32 University-street, London, W.C.
1863. §Peacock, Richard Atkinson. 12 Queen's-road, Jersey.
*Pearsall, Thomas John, F.C.S. Birkbeck Literary and Scientific Institution, Southampton-buildings, Chancery-lane, London, E.C.
Pearson, Charles. 10 Torrington-square, London, W.C.
1872. *Pearson, Joseph. 56 Welbeck-terrace, Mansfield-road, Nottingham.
1870. ‡Pearson, Rev. Samuel. 3 Greenheys-road, Prince's Park, Liverpool.
1863. §Pease, H. F. Brinkburn, Darlington.
1863. *Pease, Joseph W., M.P. Hutton Hall, near Guisborough.
1863. ‡Pease, J. W. Newcastle-on-Tyne.
1858. *Pease, Thomas, F.G.S. Cote Bank, Westbury-on-Trym, near Bristol.
Peckitt, Henry. Carlton Husthwaite, Thirsk, Yorkshire.
1855. *Peckover, Alexander, F.R.G.S. Wisbeach, Cambridgeshire.
*Peckover, Algernon, F.L.S. Harecroft House, Wisbeach, Cambridgeshire.
*Peckover, William, F.S.A. Wisbeach, Cambridgeshire.
*Peel, George. Soho Iron Works, Manchester.
1861. *Peile, George, jun. Shotley Bridge, Co. Durham.
1861. *Peiser, John. Barnfield House, 491 Oxford-street, Manchester.
1865. ‡Pemberton, Oliver. 18 Temple-row, Birmingham.
1861. *Pender, John, M.P. 18 Arlington-street, London, S.W.
1868. ‡Pendergast, Thomas. Lancefield, Cheltenham.
1856. §PENGELLY, WILLIAM, F.R.S., F.G.S. Lamorna, Torquay.
1845. ‡PERCY, JOHN, M.D., F.R.S., F.G.S., Professor of Metallurgy in the Government School of Mines. Museum of Practical Geology, Jermyn-street, S.W.; and 1 Gloucester-crescent, Hyde Park, London.
*Perigal, Frederick. Chatcots, Belsize Park, London, N.W.
1868. *PERKIN, WILLIAM HENRY, F.R.S., F.C.S. The Chestnut, Sudbury, N.W.
1861. ‡Perkins, Rev. George. St. James's View, Dickenson-road, Rusholme, near Manchester.
Perkins, Rev. R. B., D.C.L. Wotton-under-Edge, Gloucestershire.
1864. *Perkins, V. R. The Brands, Wotton-under-Edge, Gloucestershire.
1867. ‡*Perkins, William.*
1861. ‡Perring, John Shae. 104 King-street, Manchester.
Perry, The Right Rev. Charles, M.A., Bishop of Melbourne, Australia.
*Perry, Rev. S. G. F., M.A. Tottington Parsonage, near Bury.
1870. *PERRY, Rev. S. J. Stonyhurst College Observatory, Whalley, Blackburn.

Year of Election.

1861. *Petrie, John. South-street, Rochdale.
Peyton, Abel. Oakhurst, Edgbaston, Birmingham.
1871. *Peyton, John E. H., F.R.A.S. 108 Marina, St. Leonards-on-Sea.
1867. ‡PHAYRE, Colonel Sir ARTHUR. East India United Service Club, St. James's-square, London, S.W.
1863. *PHENÉ, JOHN SAMUEL, F.G.S., F.R.G.S. 5 Carlton-terrace, Oakley-street, Chelsea, London, S.W.
1870. §Philip, T. D. 51 South Castle-street, Liverpool.
1853. *Philips, Rev. Edward. Hollington, Uttoxeter, Staffordshire.
1853. *Philips, Herbert. 35 Church-street, Manchester.
*Philips, Mark. Welcombe, Stratford-on-Avon.
Philips, Robert N. The Park, Manchester.
1863. ‡Philipson, Dr. 1 Saville-row, Newcastle-on-Tyne.
1859. *PHILLIPS, Major-General Sir FROWELL. 1 Vere-street, Cavendish-square, London, W.
1862. ‡Phillips, Rev. George, D.D. Queen's College, Cambridge.
1870. §PHILLIPS, J. ARTHUR. Cressington Park, Aigburth, Liverpool.
*PHILLIPS, JOHN, M.A., LL.D., D.C.L., F.R.S., F.G.S., Professor of Geology in the University of Oxford. Museum House, Oxford.
1859. ‡*Phillips, Major J. Scott.*
1868. ‡Phipson, R. M., F.S.A. Surrey-street, Norwich.
1868. ‡PHIPSON, T. L., Ph.D. 4 The Cedars, Putney, Surrey.
1864. ‡Pickering, William. Oak View, Clevedon.
1861. ‡Pickstone, William. Radcliff Bridge, near Manchester.
1870. §Picton, J. Allanson, F.S.A. Sandyknowe, Wavertree, Liverpool.
1870. §Pigot, Rev. E. V. Malpas, Cheshire.
1871. §Pigot, Thomas F. Royal College of Science, Dublin.
1865. ‡PIKE, L. OWEN. 25 Carlton-villas, Maida Vale, London, W.
*Pike, Ebenezer. Besborough, Cork.
1857. ‡Pilkington, Henry M., M.A., Q.C. 35 Gardiner's-place, Dublin.
1863. *PIM, Captain BEDFORD C. T., R.N., F.R.G.S. Leaside, Kingswood-road, Upper Norwood, London, S.E.
Pim, George, M.R.I.A. Brennan's Town, Cabinteely, Dublin.
Pim, Jonathan. Harold's Cross, Dublin.
Pim, William H. Monkstown, Dublin.
1861. ‡Pincoffs, Simon. Crumpsall Lodge, Cheetham-hill, Manchester.
1868. ‡Pinder, T. R. St. Andrews, Norwich.
1859. ‡Pirrie, William, M.D. 238 Union-street West, Aberdeen.
1866. ‡Pitcairn, David. Dudhope House, Dundee.
1864. ‡Pitt, R. 5 Widcomb-terrace, Bath.
1869. §PLANT, JAMES, F.G.S. 40 West-terrace, West-street, Leicester.
1865. ‡Plant, Thomas L. Camp-hill, and 33 Union-street, Birmingham.
1867. ‡PLAYFAIR, Lieut.-Colonel, H.M. Consul, Algeria.
1842. PLAYFAIR, LYON, C.B., Ph.D., LL.D., M.P., F.R.S. L. & E., F.C.S. 4 Queensberry-place, South Kensington, London, S.W.
1857. ‡Plunkett, Thomas. Ballybrophy House, Borris-in-Ossory, Ireland.
1861. *POCHIN, HENRY DAVIS, M.P., F.C.S. Broughton Old Hall, Manchester.
1846. ‡POLE, WILLIAM, Mus. Doc., F.R.S. The Athenæum Club, Pall Mall, London, S.W.
*Pollexfen, Rev. John Hutton, M.A. East Wilton Vicarage, Bedale, Yorkshire.
Pollock, A. 52 Upper Sackville-street, Dublin.
1862. *Polwhele, Thomas Roxburgh, M.A., F.G.S. Polwhele, Truro, Cornwall.
1854. ‡Poole, Braithwaite. Birkenhead.
1868. ‡Pooley, Thomas A., B.Sc. South Side, Clapham Common, London, S.W.
1868. ‡Portal, Wyndham S. Malsanger, Basingstoke.

Year of Election.

*PORTER, HENRY J. KER, M.R.I.A. New Traveller's Club, 15 George-street, Hanover-square, London, W.
1866. §Porter, Robert. Beeston, Nottingham.
Porter, Rev. T. H., D.D. Desertcreat, Co. Armagh.
1863. ‡Potter, D. M. Cramlington, near Newcastle-on-Tyne.
*POTTER, EDMUND, M.P., F.R.S. Camfield-place, Hatfield, Herts.
1842. Potter, Thomas. George-street, Manchester.
1863. ‡Potts, James. 52½ Quayside, Newcastle-on-Tyne.
1857. *POUNDEN, Captain LONSDALE, F.R.G.S. Junior United Service Club, St. James's-square, London, S.W.; and Brownswood House, Enniscorthy, Co. Wexford.
1857. ‡Power, Sir James, Bart. Edermine, Enniscorthy, Ireland.
1867. ‡Powrie, James. Reswallie, Forfar.
1855. *Poynter, John E. Clyde Neuck, Uddingstone, Hamilton, Scotland.
1864. ‡Prangley, Arthur. 2 Burlington-buildings, Redland, Bristol.
1869. *Preece, William Henry. Grosvenor House, Southampton.
1864. *Prentice, Manning. Violet-hill, Stowmarket, Suffolk.
Prest, The Venerable Archdeacon Edward. The College, Durham.
Prest, John. Blossom-street, York.
*PRESTWICH, JOSEPH, F.R.S., F.G.S. Shoreham, near Sevenoaks.
1871. ‡Price, Astley Paston. 47 Lincoln's-Inn-Fields, London, W.C.
1856. *PRICE, Rev. BARTHOLOMEW, M.A., F.R.S., F.R.A.S., Sedleian Professor of Natural Philosophy in the University of Oxford. 11 St. Giles's-street, Oxford.
1872. §Price, David S., Ph.D. 26 Great George-street, Westminster, S.W.
1870. §Price, Captain E. W., M.P. Tibberton Court, Gloucester.
Price, J. T. Neath Abbey, Glamorganshire.
1865. †Prideaux, J. Symes. 209 Piccadilly, London, W.
1864. *Prior, R. C. A., M.D. 48 York-terrace, Regent's Park, London, N.W.
1865. *Prichard, Thomas, M.D. Abington Abbey, Northampton.
1835. *Pritchard, Andrew, F.R.S.E. 87 St. Paul's-road, Canonbury, London, N.
1846. *PRITCHARD, Rev. CHARLES, M.A., F.R.S., F.R.A.S., F.G.S., Professor of Astronomy in the University of Oxford. 8 Keble-terrace, Oxford.
1872. §Pritchard, Rev. W. Gee. Brignal Rectory, Barnard Castle, Co. Durham.
1871. ‡Procter, James. Morton House, Clifton, Bristol.
1863. ‡Procter, R. S. Summerhill-terrace, Newcastle-on-Tyne.
Proctor, Thomas. Elmsdale House, Clifton Down, Bristol.
Proctor, William. 108 Pembroke-road, Clifton, Bristol.
1858. §Proctor, William, M.D., F.C.S. 24 Petergate, York.
1863. *Prosser, Thomas. West Boldon, Co. Durham.
1863. ‡Proud, Joseph. South Hetton, Newcastle-on-Tyne.
1865. ‡Prowse, Albert P. Whitchurch Villa, Mannamead, Plymouth.
1872. *Pryor, M. Robert. High Elms, Watford.
1871. *Puckle, Thomas John. Woodcote-grove, Carshalton, Surrey.
1864. ‡Pugh, John. Aberdovey, Shrewsbury.
1867. ‡Pullar, John. 4 Leonard Bank, Perth.
1867. §Pullar, Robert. 6 Leonard Bank, Perth.
1842. *Pumphrey, Charles. 33 Frederick-road, Edgbaston, Birmingham.
Punnett, Rev. John, M.A., F.C.P.S. St. Earth, Cornwall.
1869. ‡Purchas, Rev. W. H. St. James's, Gloucester.
1852. ‡Purdon, Thomas Henry, M.D. Belfast.
1860. ‡PURDY, FREDERICK, F.S.S., Principal of the Statistical Department of the Poor Law Board, Whitehall, London. Victoria-road, Kensington, London, W.

Year of Election.

1866. ‡Purser, Professor John. Queen's College, Belfast.
1860. *Pusey, S. E. Bouverie-. Pusey House, Faringdon.
1861. *Pyne, Joseph John. The Portico, Mosley-street, Manchester.
1868. §Pye-Smith, P. H., M.D. 31 Finsbury-square, E.C.; and Guy's Hospital, London, S.E.

1870. †Rabbits, W. T. Forest-hill, London, S.E.
1860. ‡Radcliffe, Charles Bland, M.D. 25 Cavendish-square, London, W.
1870. ‡Radcliffe, D. R. Phœnix Safe-works, Windsor, Liverpool.
*Radford, William, M.D. Sidmount, Sidmouth.
1861. ‡Rafferty, Thomas. 13 Monmouth-terrace, Rusholme, Manchester.
1854. ‡Raffles, Thomas Stamford. 13 Abercromby-square, Liverpool.
1870. ‡Raffles, William Winter. Sunnyside, Prince's Park, Liverpool.
1859. †Rainey, George, M.D. 17 Golden-square, Aberdeen.
1855. ‡Rainey, Harry, M.D. 10 Moore-place, Glasgow.
1864. ‡Rainey, James T. 8 Widcomb-crescent, Bath.
Rake, Joseph. Charlotte-street, Bristol.
1863. ‡Ramsay, Alexander, jun., F.G.S. 45 Norland-square, Notting-hill, London, W.
1845. ‡Ramsay, Andrew Crombie, LL.D., F.R.S., F.G.S., Director-General of the Geological Survey of the United Kingdom and of the Museum of Economic Geology, Professor of Geology in the Royal School of Mines. Geological Survey Office, Jermyn-street, London, S.W.
1863. †Ramsay, D. R. Wallsend, Newcastle-on-Tyne.
1867. ‡Ramsay, James, Jun. Dundee.
1861. ‡Ramsay, John. Kildalton, Argyleshire.
1867. *Ramsay, W. F., M.D. 15 Somerset-street, Portman-square, London, W.
1835. *Rance, Henry (Solicitor). Cambridge.
1869. *Rance, H. W. Henniker. 63 St. Andrew's-street, Cambridge.
Rand, John. Wheatley-hill, Bradford, Yorkshire.
1865. ‡Randel, J. 50 Vittoria-street, Birmingham.
1860. ‡Randall, Thomas. Grandepoint House, Oxford.
1855. ‡Randolph, Charles. Pollockshiels, Glasgow.
1860. *Randolph, Rev. Herbert, M.A. Marcham, near Abingdon.
Ranelagh, the Right Hon. Lord. 7 New Burlington-street, Regent-street, London, W.
1861. §Ransome, Arthur, M.A. Bowdon, Manchester.
Ransome, Thomas. 34 Princess-street, Manchester.
1863. §Ransom, William Henry, M.D., F.R.S. Low Pavement, Nottingham.
1868. *Ranson, Edwin. Kempstone, near Bedford.
1872. *Ranyard, Arthur Cowper, F.R.A.S. 25 Old-square, Lincoln's-Inn, London, W.C.
Rashleigh, Jonathan. 3 Cumberland-terrace, Regent's Park, London, N.W.
1868. †*Rassam, Hormuzd.*
*Ratcliff, Colonel Charles, F.L.S., F.G.S., F.S.A., F.R.G.S. Wyddrington, Edgbaston, Birmingham.
1864. §Rate, Rev. John, M.A. Lapley Vicarage, Penkridge, Staffordshire.
1870. ‡Rathbone, Benson. Exchange-buildings, Liverpool.
1870. ‡Rathbone, Philip H. Greenbank Cottage, Wavertree, Liverpool.
1870. §Rathbone, R. R. 11 Rumford-street, Liverpool.
1863. ‡Rattray, W. St. Clement's Chemical Works, Aberdeen.
Rawdon, William Frederick M.D. Bootham, York.
1870. ‡Rawlins, G. W. The Hollies, Rainhill, Liverpool.
*Rawlins, John. Llewesog Hall, near Denbigh.

Year of Election.

1866. *Rawlinson, George, M.A., Camden Professor of Ancient History in the University of Oxford. The Oaks, Precincts, Canterbury.
1855. *Rawlinson, Major-General Sir Henry C., K.C.B., LL.D., F.R.S., F.R.G.S. 21 Charles-street, Berkeley-square, London, W.
1865. §Rayner, Henry. West View, Liverpool-road, Chester.
1870. ‡Rayner, Joseph (Town Clerk). Liverpool.
1852. ‡Read, Thomas, M.D. Donegal-square West, Belfast.
1865. ‡Read, William. Albion House, Epworth, Bawtry.
*Read, W. H. Rudstone, M.A., F.L.S. Blake-street, York.
1870. §Reade, Thomas M., C.E., F.C.S. Blundell Sands, Liverpool.
1862. *Readwin, Thomas Allison, M.R.I.A., F.G.S. Knockranny, Keadue, Carrick-on-Shannon, Ireland.
1852. *Redfern, Professor Peter, M.D. 4 Lower-crescent, Belfast.
1863. ‡Redmayne, Giles. 20 New Bond-street, London, W.
1863. ‡Redmayne, R. R. 12 Victoria-terrace, Newcastle-on-Tyne.
Redwood, Isaac. Cae Wern, near Neath, South Wales.
1861. *Reé, H. P. 27 Faulkner-street, Manchester.
1861. ‡Reed, Edward J., Vice-President of the Institute of Naval Architects. Chorlton-street, Manchester.
1869. ‡Reid, J. Wyatt. 40 Great Western-terrace, Bayswater, London, W.
1850. ‡Reid, William, M.D. Cruivie, Cupar, Fife.
1863. §Renals, E. 'Nottingham Express' Office, Nottingham.
1863. †Rendel, G. Benwell, Newcastle-on-Tyne.
Rennie, Sir John, Knt., F.R.S., F.G.S., F.S.A., F.R.G.S. 7 Lowndes-square, London, S.W.
1860. ‡Rennison, Rev. Thomas, M.A. Queen's College, Oxford.
1867. ‡Renny, W. W. 8 Douglas-terrace, Broughty Ferry, Dundee.
1869. ‡Révy, J. J. 16 Great George-street, Westminster, S.W.
1870. *Reynolds, Osborne, Professor of Engineering in Owens College, Manchester.
1858. §Reynolds, Richard, F.C.S. 13 Briggate, Leeds.
1871. ‡Reynolds, S. R. Royal Dublin Society, Kildare-street, Dublin.
Reynolds, William, M.D. Coeddu, near Mold, Flintshire.
1858. *Rhodes, John. 18 Albion-street, Leeds.
1868. §Richards, Rear-Admiral George H., C.B., F.R.S., F.R.G.S., Hydrographer to the Admiralty. The Admiralty, Whitehall, London, S.W.
1863. §Richardson, Benjamin Ward, M.A., M.D., F.R.S. 12 Hinde-street, Manchester-square, London, W.
1861. §Richardson, Charles. 10 Berkeley-square, Bristol.
1869. *Richardson, Charles. Albert Park, Abingdon, Berks.
1863. *Richardson, Edward, jun. 3 Lovaine-place, Newcastle-on-Tyne.
1868. *Richardson, George. 4 Edward-street, Werneth, Oldham.
1870. ‡Richardson, J. H. 3 Arundel-terrace, Cork.
1868. §Richardson, James C. Glanrafon, near Swansea.
1863. ‡Richardson, John W. South Ashfield, Newcastle-on-Tyne.
1870. ‡Richardson, Ralph. 16 Coates-crescent, Edinburgh.
Richardson, Thomas. Montpelier-hill, Dublin.
Richardson, William. Micklegate, York.
1861. §Richardson, William. 4 Edward-street, Werneth, Oldham.
1861. ‡Richson, Rev. Canon, M.A. Shakespeare-street, Ardwick, Manchester.
1863. ‡Richter, Otto, Ph.D. 7 India-street, Edinburgh.
1870. ‡Rickards, Dr. 36 Upper Parliament-street, Liverpool.
1868. §Ricketts, Charles, M.D., F.G.S. 22 Argyle-street, Birkenhead.
*Riddell, Major-General Charles J. Buchanan, C.B., F.R.S. Oaklands, Chudleigh, Devon.

Year of Election.

1861. *Riddell, Henry B. Whitefield House, Rothbury, Morpeth.
1859. ‡Riddell, Rev. John. Moffat by Beatlock, N.B.
1861. *Rideout, William J. 51 Charles-street, Berkeley-square, London, W.
1872. §Ridge, James. 98 Queen's-road, Brighton.
1862. ‡Ridgway, Henry Akroyd, B.A. Bank Field, Halifax.
1861. ‡Ridley, John. 19 Belsize-park, Hampstead, London, N.W.
1863. ‡Ridley, Samuel. 7 Regent's-terrace, Newcastle-on-Tyne.
1863. *Rigby, Samuel. Bruche Hall, Warrington.
*Ripon, The Marquis of, K.G., D.C.L., F.R.S., F.L.S. 1 Carlton-gardens, London, S.W.
1860. ‡Ritchie, George Robert. 4 Watkyn-terrace, Coldharbour-lane, Camberwell, London, S.E.
1867. ‡Ritchie, John. Fleuchar Craig, Dundee.
1855. ‡Ritchie, Robert, C.E. 14 Hill-street, Edinburgh.
1867. ‡Ritchie, William. Emslea, Dundee.
1869. *Rivington, John. 65 Porchester-terrace, Hyde Park, London, W.
1854. ‡Robberds, Rev. John, B.A. Battledown Tower, Cheltenham.
1869. *Robbins, J. 104 Portsdown-road, Maida-hill, London, N.W.
Roberton, John. Oxford-road, Manchester.
1859. ‡Roberts, George Christopher. Hull.
1859. ‡Roberts, Henry, F.S.A. Athenæum Club, London, S.W.
1870. *Roberts, Isaac, F.G.S. 26 Rock-park, Rock-ferry, Cheshire.
1857. ‡Roberts, Michael, M.A. Trinity College, Dublin.
*Roberts, William P. 38 Red-lion-square, London, W.C.
1868. §Roberts, W. Chandler, F.G.S., F.C.S. Royal Mint, London, E.
1859. ‡Robertson, Dr. Andrew. Indego, Aberdeen.
1866. ‡Robertson, Alister Stuart, M.D., F.R.G.S. Horwich, Bolton, Lancashire.
1867. §Robertson, David. Union Grove, Dundee.
1871. ‡Robertson, George, C.E., F.R.S.E. 47 Albany-street, Edinburgh.
1870. *Robertson, John. Bank, High-street, Manchester.
1866. ‡Robertson, William Tindal, M.D. Nottingham.
1861. §Robinson, Enoch. Dukinfield, Ashton-under-Lyne.
1852. ‡Robinson, Rev. George. Tartaragham Glebe, Loughgall, Ireland.
1864. ‡*Robinson, George Augustus.*
1859. ‡Robinson, Hardy. 156 Union-street, Aberdeen.
1860. ‡*Robinson, Professor H. D.*
*Robinson, H. Oliver. 6 South-street, Finsbury, London, E.C.
1866. ‡Robinson, John. Museum, Oxford.
1861. ‡Robinson, John. Atlas Works, Manchester.
1863. ‡Robinson, J. H. Cumberland-row, Newcastle-on-Tyne.
1855. ‡Robinson, M. E. 116 St. Vincent-street, Glasgow.
1860. ‡Robinson, Admiral Robert Spencer. 61 Eaton-place, London, S.W.
Robinson, Rev. Thomas Romney, D.D., F.R.S., F.R.A.S., M.R.I.A., Director of the Armagh Observatory. Armagh.
1863. ‡Robinson, T. W. U. Houghton-le-Spring, Durham.
1870. §Robinson, William. 40 Smithdown-road, Liverpool.
1870. *Robson, E. R. 20 Great George-street, Westminster, S.W.
1863. **Robson, James.*
*Robson, Rev. John, M.A., D.D. Ajmére Lodge, Cathkin-road, Langside, Glasgow.
1855. ‡Robson, Neil, C.E. 127 St. Vincent-street, Glasgow.
1872. *Robson, William. 3 Palmerston-road, Grange, Edinburgh.
1872. §Rodwell, George F., F.R.A.S., F.C.S., Lecturer on Natural Philosophy at Guy's Hospital. Marlborough College, Wiltshire.
1866. ‡Roe, Thomas. Grove Villas, Sitchurch.
1861. §Rofe, John, F.G.S. 7 Queen-street, Lancaster.

Year of Election.

1869. *Rogers, Nathaniel, M.D. 34 Paul-street, Exeter.
1860. ‡ROGERS, JAMES E. THOROLD, Professor of Economic Science and Statistics in King's College, London. Beaumont-street, Oxford.
1867. ‡Rogers, James S. Rosemill, by Dundee.
1870. ‡Rogers, T. L., M.D. Rainhill, Liverpool.
1859. ‡ROLLESTON, GEORGE, M.A., M.D., F.R.S., F.L.S., Professor of Anatomy and Physiology in the University of Oxford. The Park, Oxford.
1866. ‡Rolph, George Frederick. War Office, Horse Guards, London, S.W.
1863. ‡Romilly, Edward. 14 Hyde Park-terrace, London, W.
1845. ‡RONALDS, Sir FRANCIS, F.R.S. 9 St. Mary's-villas, Battle, Sussex.
1846. ‡Ronalds, Edmund, Ph.D. Stewartfield, Bonnington, Edinburgh.
1869. ‡Roper, C. H. Magdalen-street, Exeter.
1872. *Roper, Freeman Clark Samuel, F.G.S., F.L.S. Palgrave House, Eastbourne.
1865. ‡Roper, R. S., F.G.S. Cwmbrae Iron Works, Newport, Monmouthshire.
1855. *ROSCOE, HENRY ENFIELD, B.A., Ph.D., F.R.S., F.C.S., Professor of Chemistry in Owens College, Manchester.
1861. ‡ROSE, C. B., F.G.S. 25 King-street, Great Yarmouth, Norfolk.
1863. ‡Roseby, John. Haverholme House, Brigg, Lincolnshire.
1857. ‡Ross, David, LL.D. Drumbrain Cottage, Newbliss, Ireland.
1872. §Ross, James, M.D. Waterfoot, near Manchester.
1859. *Ross, Rev. James Coulman. Baldon Vicarage, Oxford.
1861. *Ross, Thomas. 7 Wigmore-street, Cavendish-square, London, W.
1842. Ross, William. Pendleton, Manchester.
1869. *ROSSE, The Right Hon. The Earl of, D.C.L., F.R.S., F.R.A.S. Birr Castle, Parsonstown, Ireland; and 82 Lowndes-square, London, S.W.
1865. *Rothera, George Bell. 17 Waverley-street, Nottingham.
1849. §Round, Daniel G. Hange Colliery, near Tipton, Staffordshire.
1861. ‡Routh, Edward J., M.A. St. Peter's College, Cambridge.
1872. *Row, A. V. Nursing Observatory, Daba-gardens, Vizagapatam, India (care of King & Co., 45 Pall Mall, London).
1861. ‡Rowan, David. Elliot-street, Glasgow.
1855. ‡Rowand, Alexander. Linthouse, near Glasgow.
1865. §Rowe, Rev. John. Beaufort-villas, Edgbaston, Birmingham.
1855. *ROWNEY, THOMAS H., Ph.D., F.C.S., Professor of Chemistry in Queen's College, Galway. Palmyra-crescent, Galway.
*Rowntree, Joseph. Leeds.
1862. ‡Rowsell, Rev. Evan Edward, M.A. Hambledon Rectory, Godalming.
1861. *Royle, Peter, M.D., L.R.C.P., M.R.C.S. 27 Lever-street, Manchester.
1869. §Rudler, F. W., F.G.S. 6 Pond-street, Hampstead, London, N.W.
1856. ‡Rumsay, Henry Wildbore. Gloucester Lodge, Cheltenham.
1847. ‡RUSKIN, JOHN, M.A., F.G.S., Slade Professor of Fine Arts in the University of Oxford. Corpus Christi College, Oxford.
1857. ‡Russell, Rev. C. W., D.D. Maynooth College.
1865. ‡Russell, James, M.D. 91 Newhall-street, Birmingham.
1859. ‡RUSSELL, JOHN, the Right Hon. Earl, K.G., F.R.S., F.R.G.S. 37 Chesham-place, Belgrave-square, London, S.W.
Russell, John. 15 Middle Gardiner's-street, Dublin.
RUSSELL, JOHN SCOTT, M.A., F.R.S. L. & E. Sydenham; and 5 Westminster Chambers, London, S.W.
1852. *Russell, Norman Scott. 5 Westminster-chambers, London, S.W.
1863. ‡Russell, Robert. Gosforth Colliery, Newcastle-on-Tyne.

Year of
Election.

1852. *Russell, William J., Ph.D., F.R.S., Professor of Chemistry, St. Bartholomew's Medical College. 34 Upper Hamilton-terrace, St. John's Wood, London, N.W.
1862. §Russell, W. H. L., A.B., F.R.S. 5 The Grove, Highgate, London, N.
1865. ‡Rust, Rev. James, M.A. Manse of Slains, Ellon, N.B.
1871. §Rutherford, William, M.D., Professor of Physiology in King's College, London, W.C.
Rutson, William. Newby Wiske, Northallerton, Yorkshire.
1871. ‡Ruttledge, T. E.
*Ryland, Arthur. The Linthurst Hill, Broomsgrove, near Birmingham.
1865. ‡Ryland, Thomas. The Redlands, Erdington, Birmingham.
1853. ‡Rylands, Joseph. 9 Charlotte-street, Hull.
1861. *Rylands, Thomas Glazebrook, F.L.S., F.G.S. Highfields, Thelwall, near Warrington.

*Sabine, General Sir Edward, K.C.B., R.A., LL.D., D.C.L., F.R.S., F.R.A.S., F.L.S., F.R.G.S. 13 Ashley-place, Westminster, S.W.
1865. ‡Sabine, Robert. Auckland House, Willesden-lane, London, N.W.
1871. §Sadler, Samuel Camperdowne. Purton Court, Wiltshire.
1866. *St. Albans, His Grace the Duke of. Bestwood Lodge, Arnold, near Nottingham.
1848. ‡St. Davids, The Right Rev. Connop Thirlwall, D.D., F.G.S., Lord Bishop of. Abergwili, Carmarthen.
Salkeld, Joseph. Penrith, Cumberland.
1857. ‡Salmon, Rev. George, D.D., D.C.L., F.R.S., Regius Professor of Divinity in the University of Dublin. Trinity College, Dublin.
1861. ‡*Salmon, Henry C., F.G.S., F.C.S.*
1872. §Salomons, Sir David, Bart. Broom-hill, Tunbridge Wells.
1858. *Salt, Sir Titus, Bart. Crow-Nest, Lightcliffe, near Halifax.
1872. §Salvin, Osbert, M.A., F.L.S. 32 The Grove, Boltons, London, S.W.
1842. Sambrooke, T. G. 32 Eaton-place, London, S.W.
1861. *Samson, Henry. Messrs. Samson and Leppoe, 6 St. Peter's-square, Manchester.
1867. ‡Samuelson, Edward. Roby, near Liverpool.
1870. ‡Samuelson, James. St. Domingo-grove, Everton, Liverpool.
1861. *Sandeman, Archibald, M.A. Tulloch, Perth.
1857. ‡Sanders, Gilbert. The Hill, Monkstown, Co. Dublin.
1872. §Sanders, Mrs. 8 Pouris-square, Brighton.
*Sanders, William, F.R.S., F.G.S. Hanbury Lodge, The Avenue, Clifton, Bristol.
1871. ‡Sanders, William R., M.D. 11 Walker-street, Edinburgh.
1872. §Sanderson, J. S. Burdon, M.D., F.R.S. 49 Queen Anne-street, London, W.
Sandes, Thomas, A.B. Sallow Glin, Tarbert, Co. Kerry.
1864. ‡Sandford, William. 9 Springfield-place, Bath.
1854. ‡Sandon, Right Hon. Lord, M.P. 39 Gloucester-square, London, W.
1865. ‡Sargant, W. L. Edmund-street, Birmingham.
Satterfield, Joshua. Alderley Edge.
1861. ‡Saul, Charles J. Smedley-lane, Cheetham-hill, Manchester.
1868. ‡Saunders, A., C.E. King's Lynn.
1846. ‡Saunders, Trelawney W. India Office, London, S.W.
1864. ‡Saunders, T. W., Recorder of Bath. 1 Priory-place, Bath.
1860. *Saunders, William. 3 Gladstone-terrace, Brighton.
1871. §Savage, W. D. Ellerslie House, Brighton.
1863. ‡Savory, Valentine. Cleckheaton, near Leeds.

Year of Election.

1872. §Sawyer, George David. 55 Buckingham-place, Brighton.
1868. ‡Sawyer, John Robert. Grove-terrace, Thorpe Hamlet, Norwich.
1857. ‡Scallan, James Joseph. 77 Harcourt-street, Dublin.
1850. ‡Scarth, Pillans. 2 James's-place, Leith.
1868. §Schacht, G. F. 7 Regent's-place, Clifton, Bristol.
**Schemman, J. C. Hamburg.*
1872. §SCHENCK, ROBERT, Ph.D. 398 Manor-terrace, Brixton, S.W.
*Schlick, Count Benj. Quai Voltaire, Paris.
1842. Schofield, Joseph. Stubley Hall, Littleborough, Lancashire.
*Scholes, T. Seddon. Irlam Lodge, Warwick-place, Leamington.
1847. *Scholey, William Stephenson, M.A. Freemantle Lodge, Bath-road, Reading.
SCHUNCK, EDWARD, F.R.S., F.C.S. Oaklands, Kersall Moor, Manchester.
1861. *Schwabe, Edmund Salis. Rhodes House, near Manchester.
1867. ‡*Schwendler, Louis.*
1847. ‡SCLATER, PHILIP LUTLEY, M.A, Ph.D., F.R.S., F.L.S., Sec. Zool. Soc. 11 Hanover-square, London, W.
1867. ‡SCOTT, ALEXANDER. Clydesdale Bank, Dundee.
1871. ‡Scott, Rev. C. G. 12 Pilrig-street, Edinburgh.
1872. §Scott, Major-General, C.B. Sunnyside, Ealing.
1865. §SCOTT, Major-General E. W. S., Royal Bengal Artillery. Treledan Hall, Welshpool, Montgomeryshire.
1859. ‡Scott, Captain Fitzmaurice. Forfar Artillery.
1872. §Scott, George, Curator of the Free Library and Museum, Brighton. 6 Western-cottages, Brighton.
1871. ‡Scott, James S. T. Monkrigg, Haddingtonshire.
1857. §SCOTT, ROBERT H., M.A., F.R.S., F.G.S., Director of the Meteorological Office. 116 Victoria-street, London, S.W.
1861. §Scott, Rev. Robert Selkirk, D.D. 14 Victoria-crescent, Dowanhill, Glasgow.
1864. ‡Scott, Wentworth Lascelles. Wolverhampton.
1858. ‡Scott, William. Holbeck, near Leeds.
1869. §Scott, William Bower. Chudleigh, Devon.
1864. ‡Scott, William Robson, Ph.D. St. Leonards, Exeter.
1869. ‡Searle, Francis Furlong. 5 Cathedral-yard, Exeter.
1859. ‡Seaton, John Love. Hull.
1870. ‡Seaton, Joseph, M.D. Halliford House, Sandbury.
1861. *SEELEY, HARRY GOVIER, F.L.S., F.G.S. 60 Silchester-road, Notting-hill, London, W.
1855. ‡Seligman, H. L. 135 Buchanan-street, Glasgow.
*SELWYN, Rev. Canon WILLIAM, M.A., D.D., F.R.S., Margaret Professor of Divinity in the University of Cambridge. Vine Cottage, Cambridge.
1858. *Senior, George, F.S.S. Rose-hill, Dodsworth, near Barnsley.
1870. *Sephton, Rev. J. 166 Bedford-street, Liverpool.
1868. ‡Sewell, Philip E. Catton, Norwich.
Seymour, George Hicks. Stonegate, York.
1861. *Seymour, Henry D. 209 Piccadilly, London, W.
Seymour, John. 21 Bootham, York.
1853. ‡Shackles, G. L. 6 Albion-street, Hull.
*Shaen, William. 15 Upper Phillimore-gardens, Kensington, London, S.W.
1871. *Shand, James. Eliot Bank, Sydenham-hill, London, S.E.
1867. §Shanks, James. Den Iron Works, Arbroath, N. B.
Sharp, Rev. John, B.A. Horbury, Wakefield.
1861. §SHARP, SAMUEL, F.G.S., F.S.A. Dallington Hall, near Northampton.

Year of Election.

*Sharp, William, M.D., F.R.S., F.G.S. Horton House, Rugby.
Sharp, Rev. William, B.A. Mareham Rectory, near Boston, Lincolnshire.
SHARPEY, WILLIAM, M.D., LL.D., F.R.S., F.R.S.E., Professor of Anatomy and Physiology in University College. Lawnbank, Hampstead, London, N.W.
1869. *Shapter, Lewis. The Barnfield, Exeter.
1858. *Shaw, Bentley. Woodfield House, Huddersfield.
1854. *Shaw, Charles Wright. 3 Windsor-terrace, Douglas, Isle of Man.
1870. ‡Shaw, Duncan. Cordova, Spain.
1865. †Shaw, George. Cannon-street, Birmingham.
1870. ‡Shaw, John. 24 Great George-place, Liverpool.
1845. ‡Shaw, John, M.D., F.L.S., F.G.S. Hop House, Boston, Lincolnshire.
1853. ‡Shaw, Norton, M.D. St. Croix, West Indies.
Shepard, John. Nelson-square, Bradford, Yorkshire.
1863. ‡Shepherd, A. B. 49 Seymour-street, Portman-square, London, W.
1870. §Shepherd, Joseph. 29 Everton-crescent, Liverpool.
Sheppard, Rev. Henry W., B.A. The Parsonage, Emsworth, Hants.
1869. ‡Sherard, Rev. S. H. Newton Abbot, Devon.
1851. ‡Shewell, John T. Rushmere, Ipswich.
1866. ‡Shilton, Samuel Richard Parr. Sneinton House, Nottingham.
1867. §Shinn, William C. (ASSISTANT GENERAL TREASURER). Her Majesty's Printing Office, near Fetter-lane, London, E.C.
1864. ‡*Showers, Lieut.-Colonel Charles L.*
1870. *Shoolbred, James N., F.G.S. 3 York-buildings, Dale-street, Liverpool.
1842. Shuttleworth, John. Wilton Polygon, Cheetham-hill, Manchester.
1866. ‡SIBSON, FRANCIS, M.D., F.R.S. 59 Brook-street, London, W.
1861. *Sidebotham, Joseph. 19 George-street, Manchester.
1872. *Sidebotham, Robert. Mersey Bank, Heaton Mersey, Manchester.
1861. *Sidebottom, James. Mersey Bank, Heaton Mersey, Manchester.
1857. ‡Sidney, Frederick John. 19 Herbert-street, Dublin.
Sidney, M. J. F. Cowpen, Newcastle-upon-Tyne.
1856. §SIEMENS, C. WILLIAM, D.C.L., F.R.S. 3 Great George-street, London, S.W.
*Sillar, Zechariah, M.D. Bath House, Laurie Park, Sydenham, London, S.E.
1859. ‡Sim, John. Hardgate, Aberdeen.
1871. ‡Sime, James. Craigmount House, Grange, Edinburgh.
1865. §Simkiss, T. M. Wolverhampton.
1862. ‡Simms, James. 138 Fleet-street, London, E.C.
1852. ‡Simms, William. Albion-place, Belfast.
1847. ‡Simon, John, D.C.L., F.R.S. 40 Kensington-square, London, W.
1866. ‡Simons, George. The Park, Nottingham.
1871. *SIMPSON, ALEXANDER R., M.D., Professor of Midwifery in the University of Edinburgh. 52 Queen's-street, Edinburgh.
1867. ‡Simpson, G. B. Seafield, Broughty Ferry, by Dundee.
1859. ‡Simpson, John. Marykirk, Kincardineshire.
1863. §Simpson, J. B., F.G.S. Hedgefield House, Blaydon-on-Tyne.
1857. ‡SIMPSON, MAXWELL, M.D., F.R.S., F.C.S., Professor of Chemistry in Queen's College, Cork.
*Simpson, Rev. Samuel. Greaves House, near Lancaster.
Simpson, Thomas. Blake-street, York.
Simpson, William. Bradmore House, Hammersmith, London, W.
1859. ‡Sinclair, Alexander. 133 George-street, Edinburgh.
1834. ‡Sinclair, Vetch, M.D. 48 Albany-street, Edinburgh.
1870. *Sinclair, W. P. 32 Devonshire-road, Prince's Park, Liverpool.

Year of Election.

1864. *Sircar, Baboo Mohendro Lall, M.D. 1344 San Kany, Tollah-street, Calcutta, per Messrs. Harrenden & Co., 3 Chaple-place, Poultry, London, E.C.
1865. §Sissons, William. 92 Park-street, Hull.
1850. ‡Skae, David, M.D. Royal Asylum, Edinburgh.
1870. §Sladen, Walter Percy, F.G.S. Exley House, near Halifax.
1870. §Slater, W. B. 28 Hamilton-square, Birkenhead.
1842. *Slater, William. Park-lane, Higher Broughton, Manchester.
1853. ‡Sleddon, Francis. 2 Kingston-terrace, Hull.
1849. §Sloper, George Edgar, jun. Devizes.
1849. ‡Sloper, Samuel W. Devizes.
1860. §Sloper, S. Elgar. Winterton, near Southampton.
1872. §Smale, John, Chief Justice of Hong Kong.
1867. ‡Small, David. Gray House, Dundee.
1858. ‡Smeeton, G. H. Commercial-street, Leeds.
1867. ‡Smeiton, John G. Panmure Villa, Broughty Ferry, Dundee.
1867. ‡Smeiton, Thomas A. 55 Cowgate, Dundee.
1868. §Smith, Augustus. Northwood House, Church-road, Upper Norwood, Surrey.
1857. ‡Smith, Aquila, M.D., M.R.I.A. 121 Lower Bagot-street, Dublin.
Smith, Rev. B., F.S.A.
1872. *Smith, Basil Woodd, F.R.A.S. Branch Hill Lodge, Hampstead-heath, London, N.W.
1865. §SMITH, DAVID, F.R.A.S. 4 Cherry-street, Birmingham.
1859. ‡SMITH, EDWARD, M.D., LL.B., F.R.S. 140 Harley-street, London, W.
1865. ‡Smith, Frederick. The Priory, Dudley.
1866. *Smith, F. C., M.P. Bank, Nottingham.
1855. ‡Smith, George. Port Dundas, Glasgow.
1855. ‡Smith, George Cruickshank. 19 St. Vincent-place, Glasgow.
*SMITH, Rev. GEORGE SIDNEY, D.D., M.R.I.A., Professor of Biblical Greek in the University of Dublin. Riverland, Omagh, Ireland.
*SMITH, HENRY JOHN STEPHEN, M.A., F.R.S., F.C.S., Savilian Professor of Geometry in the University of Oxford. 64 St. Giles's, Oxford.
1860. *Smith, Heywood, M.A., M.D. 2 Portugal-street, Grosvenor-square, London, W.
1865. ‡Smith, Isaac. 26 Lancaster-street, Birmingham.
1870. ‡Smith, James. 146 Bedford-street South, Liverpool.
1842. *Smith, James. Berkeley House, Seaforth, near Liverpool.
1853. ‡Smith, John. York City and County Bank, Malton, Yorkshire.
1871. *Smith, John Alexander, M.D., F.R.S.E. 7 West Maitland-street, Edinburgh.
1858. *Smith, John Metcalf. Old Bank, Leeds.
1867. §Smith, John P., C.E. 67 Renfield-street, Glasgow.
Smith, John Peter George. Spring Bank, Anfield, Liverpool.
1852. *Smith, Rev. Joseph Denham. Bellevue, Blackrock, Co. Dublin.
*Smith, Philip, B.A. 26 South-hill-park, Hampstead, London, N.W.
1860. *Smith, Protheroe, M.D. 42 Park-street, Grosvenor-square, London, W.
1837. Smith, Richard Bryan. Villa Nova, Shrewsbury.
1847. §SMITH, ROBERT ANGUS, Ph.D., F.R.S., F.C.S. 22 Devonshire-street, Manchester.
*Smith, Robert Mackay. 4 Bellevue-crescent, Edinburgh.
1870. ‡Smith, Samuel. Bank of Liverpool, Liverpool.
1866. §Smith, Samuel. 33 Compton-street, Goswell-road, London, E.C.
1867. ‡Smith, Thomas (Sheriff). Dundee.

Year of Election.

1867. ‡Smith, Thomas. Pole Park Works, Dundee.
1859. ‡Smith, Thomas James, F.G.S., F.C.S. Hessle, near Hull.
1852. ‡Smith, William. Eglinton Engine Works, Glasgow.
1857. §SMITH, WILLIAM, C.E., F.G.S., F.R.G.S. 19 Salisbury-street, Adelphi, London, W.C.
1871. ‡Smith, William Robertson. Aberdeen.
1850. *SMYTH, CHARLES PIAZZI, F.R.S. L. & E., F.R.A.S., Astronomer Royal for Scotland, Professor of Practical Astronomy in the University of Edinburgh. 15 Royal-terrace, Edinburgh.
1870. §Smyth, Colonel H. A., R.A. Barrackpore, near Calcutta.
1870. ‡Smyth, H. L. Crabwall Hall, Cheshire.
1857. *SMYTH, JOHN, jun., M.A., M.I.C.E.I., F.M.S. Milltown, Banbridge, Ireland.
1868. ‡Smyth, Rev. J. D. Hurst. 13 Upper St. Giles's-street, Norwich.
1864. ‡SMYTH, WARINGTON W., M.A., F.R.S., F.G.S., F.R.G.S., Lecturer on Mining and Mineralogy at the Royal School of Mines, and Inspector of the Mineral Property of the Crown. 92 Inverness-terrace, Bayswater, London, W.
1851. ‡Smythe, Colonel W. J., R.A., F.R.S. Bombay.
Soden, John. Athenæum Club, Pall Mall, London, S.W.
1853. ‡Sollitt, J. D., Head Master of the Grammar School, Hull.
*SOLLY, EDWARD, F.R.S., F.L.S., F.G.S., F.S.A. Sandcotes, near Poole.
*SOPWITH, THOMAS, M.A., F.R.S., F.G.S., F.R.G.S. 103 Victoria-street, Westminster, S.W.
Sorbey, Alfred. The Rookery, Ashford, Bakewell.
1859. *SORBY, H. CLIFTON, F.R.S., F.G.S. Broomfield, Sheffield.
1865. *Southall, John Tertius. Leominster.
1859. ‡Southall, Norman. 44 Cannon-street West, London, E.C.
1856. ‡Southwood, Rev. T. A. Cheltenham College.
1863. ‡Sowerby, John. Shipcote House, Gateshead, Durham.
1863. *Spark, H. King. Greenbank, Darlington.
1859. ‡Spence, Rev. James, D.D. 6 Clapton-square, London, N.E.
*Spence, Joseph. 60 Holgate Hill, York.
1869. *Spence, J. Berger. Erlington House, Manchester.
1854. §Spence, Peter. Pendleton Alum Works, Newton Heath; and Smedley Hall, near Manchester.
1861. ‡Spencer, John Frederick. 28 Great George-street, London, S.W.
1861. *Spencer, Joseph. Bute House, Old Nafford, Manchester.
1863. *Spencer, Thomas. The Grove, Ryton, near Blaydon-on-Tyne.
1855. ‡Spens, William. 78 St. Vincent-street, Glasgow.
1871. ‡Spicer, George. Broomfield, Halifax.
1864. *Spicer, Henry, jun., F.L.S., F.G.S. 22 Highbury-crescent; and 19 New Bridge-street, Blackfriars, London, E.C.
1864. §Spicer, William R. 19 New Bridge-street, Blackfriars, London, E.C.
1847. *Spiers, Richard James, F.S.A. Oxford.
1868. *Spiller, Edmund Pim. 3 Furnival's Inn, London, E.C.
1864. *SPILLER, JOHN, F.C.S. 35 Grosvenor-road, Highbury-new-park, London, N.
1846. *SPOTTISWOODE, WILLIAM, M.A., LL.D., F.R.S., F.R.A.S., F.R.G.S. (GENERAL TREASURER). 50 Grosvenor-place, London, S.W.
1864. *Spottiswoode, W. Hugh. 50 Grosvenor-place, London, S.W.
1854. *Sprague, Thomas Bond. 4 Lansdowne-place, Blackheath, London, S.E.
1853. ‡Spratt, Joseph James. West Parade, Hull.
Square, Joseph Elliot, F.G.S. 24 Portland-place, Plymouth.
*Squire, Lovell. The Observatory, Falmouth.

Year of Election.

1858. *STAINTON, HENRY T., F.R.S., Sec.L.S., F.G.S. Mountsfield, Lewisham, Kent.
1851. *Stainton, James Joseph, F.L.S. Horsell, near Ripley, Surrey.
1865. §STANFORD, EDWARD C. C. Edinbarnet, Dumbartonshire.
STANLEY, The Very Rev. ARTHUR PENRHYN, D.D., F.R.S., Dean of Westminster. The Deanery, Westminster, London, S.W.
Stapleton, H. M. 1 Mountjoy-place, Dublin.
1866. §Starey, Thomas R. Daybrook House, Nottingham.
Staveley, T. K. Ripon, Yorkshire.
1870. ‡Stearn, C. H. 3 Elden-terrace, Rock Ferry, Liverpool.
1857. ‡Steel, William Edward, M.D. 15 Hatch-street, Dublin.
1863. §Steele, Rev. Dr. 2 Bathwick-terrace, Bath.
1861. †Steinthal, H. M. Hollywood, Fallowfield, near Manchester.
1872. §Stennett, Mrs. Eliza. 2 Clarendon-terrace, Brighton.
STENHOUSE, JOHN, LL.D., F.R.S., F.C.S. 17 Rodney-street, Pentonville, London, N.
1861. *Stern, S. J. Rusholme House, Manchester.
1863. §Sterriker, John. Driffield.
1872. §Sterry, William. Union Club, Pall Mall, London, S.W.
1870. *Stevens, Miss Anna Maria. Wylye, near Heytesbury, Bath.
1861. *Stevens, Henry, F.S.A., F.R.G.S. 4 Trafalgar-square, London, W.C.
1863. *Stevenson, Archibald. 2 Wellington-crescent, South Shields.
1850. ‡Stevenson, David. 8 Forth-street, Edinburgh.
1868. ‡Stevenson, Henry, F.L.S. Newmarket-road, Norwich.
1863. *STEVENSON, JAMES C., M.P. Westoe, South Shields.
1855. ‡STEWART, BALFOUR, M.A., LL.D., F.R.S., Professor of Natural Philosophy in Owens College, Manchester. Owens College, Manchester.
1864. ‡STEWART, CHARLES, F.L.S. 19 Princess-square, Plymouth.
1856. *Stewart, Henry Hutchinson, M.D., M.R.I.A. 71 Eccles-street, Dublin.
1869. §STEWART, J. L. East India United Service Club, 14 St. James's-square, London, S.W.
1847. ‡Stewart, Robert, M.D. The Asylum, Belfast.
1867. †Stirling, Dr. D. Perth.
1868. §Stirling, Edward. 34 Queen's-gardens, Hyde Park, London, W.
1867. *Stirrup, Mark. 21 Heywood-street, Moss Side, Manchester.
1865. *Stock, Joseph S. Showell Green, Spark Hill, near Birmingham.
1862. †Stockil, William. 5 Church-meadows, Sydenham, London, S.E.
Stoddart, George. 11 Russell-square, London, W.C.
1864. §STODDART, WILLIAM WALTER, F.G.S., F.C.S. 7 King-square, Bristol.
1854. ‡Stoess, Le Chevalier, Ch. de W. (Bavarian Consul). Liverpool.
*STOKES, GEORGE GABRIEL, M.A., D.C.L., LL.D., Sec. R.S., Lucasian Professor of Mathematics in the University of Cambridge. Lensfield Cottage, Lensfield-road, Cambridge.
1862. ‡STONE, EDWARD JAMES, M.A., F.R.S., F.R.A.S., Astronomer Royal at the Cape of Good Hope. Cape Town.
1859. ‡Stone, Dr. William H. 13 Vigo-street, London, W.
1857. ‡STONEY, BINDON B., M.R.I.A., Engineer of the Port of Dublin. 42 Wellington-road, Dublin.
1861. *STONEY, GEORGE JOHNSTONE, M.A., F.R.S., M.R.I.A., Secretary to the Queen's University, Ireland. Weston House, Dundrum, Co. Dublin.
1854. ‡Store, George. Prospect House, Fairfield, Liverpool.
1867. ‡STORRAR, JOHN, M.D. Heathview, Hampstead, London, N.W.
1859. §Story, James. 17 Bryanston-square, London, W.

Year of Election.

1871. *STRACHEY, Major-General, RICHARD, R.E., F.R.S., F.L.S., F.G.S. The Rectory House, Clapham Common, London, S.W.
1863. ‡Straker, John. Wellington House, Durham.
1868. ‡STRANGE, Lieut.-Colonel A., F.R.S., F.R.A.S., F.R.G.S. India Stores, Belvedere-road, Lambeth, London, S.E.
*Strickland, Charles. Loughglyn House, Castherea, Ireland.
Strickland, William. French-park, Roscommon, Ireland.
1859. ‡Stronach, William, R.E. Ardmellie, Banff.
1867. ‡Stronner, D. 14 Princess-street, Dundee.
1866. *STRUTT, The Hon. ARTHUR, F.G.S. Milford House, Derby.
1868. *STRUTT, The Hon. JOHN W. 4 Carlton Gardens, Pall Mall, London, S.W.
1872. *Stuart, Edward A. Sudbury-hill, Harrow.
1866. ‡*Stubbins, Henry.*
1864. ‡Style, Sir Charles, Bart. 102 New Sydney-place, Bath.
1857. ‡SULLIVAN, WILLIAM K., Ph.D., M.R.I.A. Museum of Irish Industry; and 53 Upper Leeson-road, Dublin.
1863. ‡Sutherland, Benjamin John. 10 Oxford-street, Newcastle-on-Tyne.
1862. *SUTHERLAND, GEORGE GRANVILLE WILLIAM, Duke of, K.G., F.R.G.S. Stafford House, London, S.W.
1855. ‡Sutton, Edwin. 44 Winchester-street, Pimlico, London, S.W.
1863. §SUTTON, FRANCIS, F.C.S. Bank Plain, Norwich.
1861. *Swan, Patrick Don S. Kirkaldy, N.B.
1862. *SWAN, WILLIAM, LL.D., F.R.S.E., Professor of Natural Philosophy in the University of St. Andrews. 2 Hope-street, St. Andrews, N.B.
1862. *Swann, Rev. S. Kirke. Gedling, near Nottingham.
Sweetman, Walter, M.A., M.R.I.A. 4 Mountjoy-square North, Dublin.
1870. *Swinburn, Sir John. Capheaton, Newcastle-on-Tyne.
1863. ‡Swindell, J. S. E. Summerhill, Kingswinford, Dudley.
1863. ‡SWINHOE, ROBERT, F.R.G.S. 33 Oakley-square, S.W.; and Oriental Club, London, W.
1847. ‡Sykes, H. P. 47 Albion-street, Hyde Park, London, W.
1862. ‡Sykes, Thomas. Cleckheaton, near Leeds.
1847. ‡Sykes, Captain W. H. F. 47 Albion-street, Hyde Park, London. W.
SYLVESTER, JAMES JOSEPH, M.A., LL.D., F.R.S. 60 Maddox-street, W., and Athenæum Club, London, S.W.
1870. §SYMES, RICHARD GLASCOTT, F.G.S., Geological Survey of Ireland. 14 Hume-street, Dublin.
1856. *Symonds, Frederick, F.R.C.S. 35 Beaumont-street, Oxford.
1859. ‡Symonds, Captain Thomas Edward, R.N. 10 Adam-street, Adelphi, London, W.C.
1860. ‡SYMONDS, Rev. W. S., M.A., F.G.S. Pendock Rectory, Worcestershire.
1859. §SYMONS, G. J., F.M.S. 62 Camden-square, London, N.W.
1855. *SYMONS, WILLIAM, F.C.S. 26 Joy-street, Barnstaple.
1872. §Synge, Colonel, R.E. United Service Club, Pall Mall, S.W.
Synge, Francis. Glanmore, Ashford, Co. Wicklow.

1865. ‡Tailyour, Colonel Renny, R.E. Newmanswalls, Montrose, N. B.
1871. ‡TAIT, PETER GUTHRIE, F.R.S.E., Professor of Natural Philosophy in the University of Edinburgh. 17 Drummond-place, Edinburgh.
1867. ‡Tait, P. M., F.R.G.S. 26 Adelaide-road, N.; and Oriental Club, Hanover-square, London, W.
§Talbot, William Hawkshead. Hartwood Hall, Chorley, Lancashire.
TALBOT, WILLIAM HENRY FOX, M.A., LL.D., F.R.S., F.L.S. Lacock Abbey, near Chippenham.
Taprell, William. 7 Westbourne-crescent, Hyde Park, London, W.

Year of Election.

1866. ‡Tarbottom, Marrott Ogle, M.I.C.E., F.G.S. Newstead-grove, Nottingham.
1861. *Tarratt, Henry W. Bushbury Lodge, Leamington.
1856. ‡Tartt, William Macdonald, F.S.S. Sandford-place, Cheltenham.
1857. *Tate, Alexander. 2 Queen's-elms, Belfast.
1863. ‡Tate, John. Alnmouth, near Alnwick, Northumberland.
1870. ‡Tate, Norman A. 7 Nivell-chambers, Fazackerley-street, Liverpool.
1865. ‡TATE, THOMAS. White Horse Hill, Chislehurst, Kent.
1858. *Tatham, George. Springfield Mount, Leeds.
1864. *TAWNEY, EDWARD B., F.G.S. 16 Crescent, Clifton, Bristol.
1871. ‡Tayler, William, F.S.A., F.S.S. 28 Park-street, Grosvenor-square, London, W.
1867. ‡Taylor, Rev. Andrew. Dundee.
Taylor, Frederick. Laurel-cottage, Rainhill, near Prescot, Lancashire.
*Taylor, James. Culverlands, near Reading.
*TAYLOR, JOHN, F.G.S. 6 Queen-street-place, Upper Thames-street, London, E.C.
1861. *Taylor, John, jun. 6 Queen-street-place, London, E.C.
1865. ‡Taylor, Joseph. 99 Constitution-hill, Birmingham.
Taylor, Captain P. Meadows, in the Service of His Highness the Nizam. Harold Cross, Dublin.
*TAYLOR, RICHARD, F.G.S. 6 Queen-street-place, Upper Thames-street, London, E.C.
1870. §Taylor, Thomas. Aston Rowant, Tetsworth, Oxon.
*Taylor, William Edward. Millfield House, Enfield, near Accrington.
1858. ‡Teale, Thomas Pridgin, jun. 20 Park-row, Leeds.
1869. ‡Teesdale, C. S. M. Pennsylvannia, Exeter.
1863. ‡Tennant, Henry. Saltwell, Newcastle-on-Tyne.
*TENNANT, JAMES, F.G.S., F.R.G.S., Professor of Mineralogy in King's College. 149 Strand, London, W.C.
1857. ‡Tennison, Edward King. Kildare-street Club House, Dublin.
1866. ‡Thackeray, J. L. Arno Vale, Nottingham.
1859. ‡Thain, Rev. Alexander. New Machar, Aberdeen.
1871. ‡Thin, James. 7 Rillbank-terrace, Edinburgh.
1871. §THISELTON-DYER, W. T., B.A., B.Sc. 118 King Henry's-road, London, N.W.
1835. Thom, John. Lark-hill, Chorley, Lancashire.
1870. ‡Thom, Robert Wilson. Lark Hill, Chorley, Lancashire.
1871. §Thomas, Ascanius William Nevill. Chudleigh, Devon.
Thomas, George. Brislington, Bristol.
1869. ‡Thomas, H. D. Fore-street, Exeter.
1869. §Thomas, J. Henwood, F.R.G.S. Custom House, London, E.C.
*Thompson, Corden, M.D. 84 Norfolk-street, Sheffield.
1863. ‡Thompson, Rev. Francis. St. Giles's, Durham.
1858. *Thompson, Frederick. South Parade, Wakefield.
1859. §Thompson, George, jun. Pidsmedden, Aberdeen.
Thompson, Harry Stephen. Kirby Hall, Great Ouseburn, Yorkshire.
Thompson, Henry Stafford. Fairfield, near York.
1861. *Thompson, Joseph. Woodlands, Fulshaw, near Manchester.
1864. ‡THOMPSON, Rev. JOSEPH HESSELGRAVE, B.A. Cradley, near Brierley-hill.
Thompson, Leonard. Sheriff-Hutton Park, Yorkshire.
THOMPSON, THOMAS. Welton, Brough, Yorkshire.
1863. ‡Thompson, William. 11 North-terrace, Newcastle-on-Tyne.
1867. ‡Thoms, William. Magdalen-yard-road, Dundee.

Year of Election.

1855. ‡THOMSON, ALLEN, M.D., LL.D., F.R.S., Professor of Anatomy in the University of Glasgow.
1867. ‡Thomson, Francis Hay, M.D. Glasgow.
1852. ‡Thomson, Gordon A. Bedeque House, Belfast.
Thomson, Guy. Oxford.
1870. ‡THOMSON, Sir HENRY, M.D. 35 Wimpole-street, London. W.
1855. ‡Thomson, James. 82 West Nile-street, Glasgow.
1850. *THOMSON, Professor JAMES, M.A., LL.D., C.E. 17 University-square, Belfast.
1868. §THOMSON, JAMES, F.G.S. 276 Eglington-street, Glasgow.
*Thomson, James Gibson. 14 York-place, Edinburgh.
1871. *Thomson, John Millar, F.C.S. King's College, London, W.C.
1863. ‡Thomson, M. 8 Meadow-place, Edinburgh.
1872. §Thomson, Peter. 34 Granville-street, Glasgow.
1871. ‡Thomson, Robert, LL.B. 12 Rutland-square, Edinburgh,
1865. ‡Thomson, R. W., C.E., F.R.S.E. 3 Moray-place, Edinburgh.
1847. *THOMSON, Sir WILLIAM, M.A., LL.D., D.C.L., F.R.S. L. & E., PRESIDENT, Professor of Natural Philosophy in the University of Glasgow. The College, Glasgow.
1850. ‡THOMSON, THOMAS, M.D., F.R.S., F.L.S. Kew Green, Kew.
1871. §Thomson, William Burnes. 11 St. John's-street, Edinburgh.
1870. ‡Thomson, W. C., M.D. 7 Domingo-vale, Everton, Liverpool.
1850. ‡THOMSON, WYVILLE T. C., LL.D., F.R.S., F.G.S., Regius Professor of Natural History in the University of Edinburgh. 20 Palmerston-place, Edinburgh.
1871. ‡Thorburn, Rev. David, M.A. 1 John's-place, Leith.
1852. ‡Thorburn, Rev. William Reid, M.A. Starkies, Bury, Lancashire.
1865. *Thornley, S. Gilbertstone House, Bickenhill, near Birmingham.
1866. ‡Thornton, James. Edwalton, Nottingham.
*Thornton, Samuel. Oakfield, Moseley, near Birmingham.
1867. ‡Thornton, Thomas. Dundee.
1845. ‡Thorp, Dr. Disney. Suffolk Laun, Cheltenham.
1871. §Thorp, Henry. Whalley Range, Manchester.
*THORP, The Venerable THOMAS, B.D., F.G.S., Archdeacon of Bristol. Kemerton, near Tewkesbury.
1864. *THORP, WILLIAM, jun., F.C.S. 39 Sandringham-road, West Hackney, London, N.E.
1871. §THORPE, T. E., Professor of Chemistry, Andersonian University, Glasgow. The College, Glasgow.
1868. ‡Thuillier, Colonel. 27 Lower Seymour-street, Portman-square, London, W.
Thurnam, John, M.D. Devizes.
1870. ‡Tichborne, Charles R. S., F.C.S. Apothecaries' Hall of Ireland, Dublin.
1865. §Timmins, Samuel. Elvetham-road, Edgbaston, Birmingham.
Tinker, Ebenezer. Mealhill, near Huddersfield.
*TINNÉ, JOHN A., F.R.G.S. Briarly, Aigburth, Liverpool.
1861. *TODHUNTER, ISAAC, M.A., F.R.S. Principal Mathematical Lecturer St. John's College, Cambridge. Bourne House, Cambridge.
Todhunter, J. 3 College-green, Dublin.
1857. ‡Tombe, Rev. H. J. Ballyfree, Ashford, Co. Wicklow.
1856. ‡Tomes, Robert Fisher. Welford, Stratford-on-Avon.
1864. *TOMLINSON, CHARLES, F.R.S., F.C.S. 3 Ridgmount-terrace, Highgate, London, N.
1863. ‡Tone, John F. Jesmond-villas, Newcastle-on-Tyne.
1865. §Tonks, Edmund, B.C.L. Packwood Grange, Knowle, Warwickshire.

Year of Election.

1865. §Tonks, William Henry. 4 Carpenter-road, Edgbaston, Birmingham.
1861. *Topham, John, A.I.C.E. High Elms, 265 Mare-street, Hackney, London, N.E.
1872. *Topley, William, F.G.S. Geological Survey Office, Jermyn-street, London, S.W.
1863. ‡Torrens, R. R., M.P. 2 Gloucester-place, Hyde Park, London, W.
1859. ‡Torry, Very Rev. John, Dean of St. Andrews. Coupar Angus, N.B.
Towgood, Edward. St. Neots, Huntingdonshire.
1860. ‡Townsend, John. 11 Burlington-street, Bath.
1857. ‡Townsend, Rev. Richard, M.A., F.R.S., Professor of Natural Philosophy in the University of Dublin. Trinity College, Dublin.
1861. ‡Townsend, William. Attleborough Hall, near Nuneaton.
1854. ‡Towson, John Thomas, F.R.G.S. 47 Upper Parliament-street, Liverpool; and Local Marine Board, Liverpool.
1859. ‡Trail, Samuel, D.D., LL.D. The Manse, Hanay, Orkney.
1870. ‡Traill, William A. Geological Survey of Ireland, 14 Hume-street, Dublin.
1868. ‡Traquair, Ramsay H., M.D., Professor of Zoology, Royal College of Science, Dublin.
1865. ‡Travers, William, F.R.C.S. 1 Bath-place, Kensington, London, W.
Tregelles, Nathaniel. Neath Abbey, Glamorganshire.
1868. ‡Trehane, John. Exe View Lawn, Exeter.
1869. ‡Trehane, John, jun. Bedford-circus, Exeter.
1870. ‡Trench, Dr. Municipal Offices, Dale-street, Liverpool.
Trench, F. A. Newlands House, Clondalkin, Ireland.
*Trevelyan, Arthur. Tyneholme Tranent, Haddingdonshire.
Trevelyan, Sir Walter Calverley, Bart., M.A., F.R.S.E., F.G.S., F.S.A., F.R.G.S. Athenæum Club, London, S.W.; Wallington, Northumberland; and Nettlecombe, Somerset.
1871. §Tribe, Alfred. 73 Artesian-road, Bayswater, London.
1871. ‡Trimen, Roland, F.L.S., F.Z.S. Colonial Secretary's Office, Cape Town, Cape of Good Hope.
1860. §Tristram, Rev. Henry Baker, M.A., LL.D., F.R.S., F.L.S. Greatham Hospital, near Stockton-on-Tees.
1869. ‡Troyte, C. A. W. Huntsham Court, Bampton, Devon
1864. ‡Truell, Robert. Ballyhenry, Ashford. Co. Wicklow.
1869. ‡Tucker, Charles. Marlands, Exeter.
1847. *Tuckett, Francis Fox. 10 Balwin-street, Bristol.
Tuckett, Frederick. 4 Mortimer-street, Cavendish-square, London, W.
Tuke, James H. Bank, Hitchen.
1871. ‡Tuke, J. Batty, M.D. Cupar, Fifeshire.
1867. ‡Tulloch, The Very Rev. Principal, D.D. St. Andrews, Fifeshire.
1865. ‡Turbervile, H. Pilton, Barnstaple.
1854. ‡Turnbull, James, M.D. 86 Rodney-street, Liverpool.
1855. §Turnbull, John. 37 West George-street, Glasgow.
1856. ‡Turnbull, Rev. J. C. 8 Bays-hill Villas, Cheltenham.
*Turnbull, Rev. Thomas Smith, M.A., F.R.S., F.G.S., F.R.G.S. Blofield, Norfolk.
1871. §Turnbull, William. 14 Lansdowne-crescent, Edinburgh.
Turner, Thomas, M.D. 31 Curzon-street, Mayfair, London, W.
1863. *Turner, William, M.B., F.R.S.E., Professor of Anatomy in the University of Edinbugh. 6 Eaton-terrace, Edinburgh.
1842. Twamley, Charles, F.G.S. 11 Regent's-park-road, London, N.W.
1847. ‡Twiss, Sir Travers, D.C.L., F.R.S., F.R.G.S. 19 Park-lane, London, W.

Year of
Election.
1865. §Tylor, Edward Burnett, F.R.S. Lindon, Wellington, Somerset.
1858. *Tyndall, John, LL.D., Ph.D., F.R.S., F.G.S., Professor of Natural Philosophy in the Royal Institution. Royal Institution, Albemarle-street, London, W.
1861. *Tysoe, John. Seedley-road, Pendleton, near Manchester.

1872. §Upward, Alfred. 11 Great Queen's-street, Westminster, London, W.
1855. ‡Ure, John. 114 Montrose-street, Glasgow.
1859. ‡Urquhart, Rev. Alexander. Tarbat, Ross-shire.
1859. ‡Urquhart, W. Pollard. Craigston Castle, N.B.; and Castlepollard, Ireland.
1866. §Urquhart, William W. Rosebay, Broughty Ferry, by Dundee.

1870. ‡Vale, H. H. 42 Prospect-vale, Fairfield, Liverpool.
*Vallack, Rev. Benjamin W. S. St. Budeaux, near Plymouth.
*Vance, Rev. Robert. 24 Blackhall-street, Dublin.
1863. ‡Vandoni, le Commandeur Comte de, Chargé d'Affaires de S. M. Tunisienne, Geneva.
1853. §Varley, Cornelius. 337 Kentish Town-road, London, N.W.
1854. ‡Varley, Cromwell F., F.R.S. Fleetwood House, Beckenham, Kent.
1868. §Varley, Frederick H., F.R.A.S. Mildmay Park Works, Mildmay Avenue, Stoke Newington, London, N.
1865. *Varley, S. Alfred. 66 Roman-road, Holloway, London, N.
1870. §Varley, Mrs. S. A. 66 Roman-road, Holloway-road, London, N.
1869. ‡Varwell, P. Alphington-street, Exeter.
1863. ‡Vauvert, de Mean A., Vice-Consul for France. Tynemouth.
1849. *Vaux, Frederick. Central Telegraph Office, Adelaide, South Australia.
Verney, Sir Harry, Bart., M.P. Lower Claydon, Buckinghamshire.
Vernon, George John, Lord. 32 Curzon-street, London, W.; and Sudbury Hall, Derbyshire.
1866. ‡Vernon, Rev. E. H. Harcourt. Cotgrave Rectory, near Nottingham.
1854. *Vernon, George V., F.R.A.S. 1 Osborne-place, Old Trafford, Manchester.
1854. *Vernon, John. Litherland Park, Litherland, Liverpool.
1864. *Vicary, William, F.G.S. The Priory, Colleton-cresent, Exeter.
1854. *Vignoles, Charles B., C.E., F.R.S., M.R.I.A., F.R.A.S., V.P.I.C.E. 21 Duke-street, Westminster, S.W.
1868. ‡Vincent, Rev. William. Postwick Rectory, near Norwich.
1856. ‡Vivian, Edward, B.A. Woodfield, Torquay.
*Vivian, H. Hussey, M.P., F.G.S. Park Wern, Swansea; and 27 Belgrave-square, London, S.W.
1856. §Voelcker, J. Ch. Augustus, Ph.D., F.R.S., F.C.S., Professor of mistry to the Royal Agricultural Society of England. 39 Argyll-road, Kensington, London, W.
‡Vose, Dr. James. Gambier-terrace, Liverpool.

1860. §Waddingham, John. Guiting Grange, Winchcombe, Gloucestershire.
1859. ‡Waddington, John. New Dock Works, Leeds.
1855. *Waldegrave, The Hon. Granville. 26 Portland-place, London, W.
1870. ‡Waley, Jacob. 20 Wimpole-street, London, W.
1869. *Walford, Cornelius. Enfield House, Belsize-park-gardens, London, N.W.
1870. §Wake, Charles Staniland. 10 Story-street, Hull.
1849. §Walker, Charles V., F.R.S., F.R.A.S. Fernside Villa, Redhill, near Reigate.

Year of Election.

Walker, Sir Edward S. Berry Hill, Mansfield.
Walker, Francis, F.L.S., F.G.S. Elm Hall, George-lane, Wanstead, Essex, E.
Walker, Frederick John. The Priory, Bathwick, Bath.
1866. ‡Walker, H. Westwood, Newport, by Dundee.
1859. ‡Walker, James. 16 Norfolk-crescent, London, W.
1855. ‡Walker, John. 1 Exchange-court, Glasgow.
1842. *Walker, John. Thorncliffe, New Kenilworth-road, Leamington.
1866. *Walker, J. F. Sidney College, Cambridge.
1867. *Walker, Peter G. Dundee.
1866. ‡Walker, S. D. 38 Hampden-street, Nottingham.
1869. *Walker, Thomas F. W., M.A., F.R.G.S. 6 Brock-street, Bath.
Walker, William. 47 Northumberland-street, Edinburgh.
1869. ‡Walkey, J. E. C. High-street, Exeter.
Wall, Rev. R. H., M.A. 6 Hume-street, Dublin.
1863. §Wallace, Alfred R., F.R.G.S. The Dell, Grays, Essex.
1859. ‡Wallace, William, Ph.D., F.C.S. Chemical Laboratory, 3 Bath-street, Glasgow.
1857. ‡Waller, Edward. Lisenderry, Aughnacloy, Ireland.
1862. ‡Wallich, George Charles, M.D., F.L.S. 60 Holland-road, Kensington, London, W.
Wallinger, Rev. William. Hastings.
1862. †Walpole, The Right Hon. Spencer Horatio, M.A., D.C.L., M.P., F.R.S. Ealing, London, W.
1857. ‡Walsh, Albert Jasper. 89 Harcourt-street, Dublin.
Walsh, John (Prussian Consul). 1 Sir John's Quay, Dublin.
1863. ‡Walters, Robert. Eldon-square, Newcastle-on-Tyne.
Walton, Thomas Todd. Mortimer House, Clifton, Bristol.
1863. ‡Wanklyn, James Alfred, F.R.S.E., F.C.S. 3 Great Winchester-street-buildings, London, E.C.
1872. §Warburton, Benjamin. Leicester.
1857. ‡Ward, John S. Prospect-hill, Lisburn, Ireland.
Ward, Rev. Richard, M.A. 12 Eaton-place, London, S.W.
1863. ‡Ward, Robert. Dean-street, Newcastle-on-Tyne.
*Ward, William Sykes, F.C.S. 12 Bank-street, and Denison Hall, Leeds.
1867. ‡Warden, Alexander J. Dundee.
1858. ‡Wardle, Thomas. Leek Brook, Leek, Staffordshire.
1865. ‡Waring, Edward John, M.D., F.L.S. 49 Clifton-gardens, Maida-vale, London, W.
1864. *Warner, Edward. 49 Grosvenor-place, London, S.W.
1872. *Warner, Thomas. 47 Sussex-square, Brighton.
1856. ‡Warner, Thomas H. Lee. Tiberton Court, Hereford.
1869. ‡Warren, James L. Letterfrack, Galway.
1865. *Warren, Edward P., L.D.S. 13 Old-square, Birmingham.
Warwick, William Atkinson. Wyddrington House, Cheltenham.
1856. ‡Washbourne, Buchanan, M.D. Gloucester.
*Waterhouse, John, F.R.S., F.G.S., F.R.A.S. Wellhead, Halifax, Yorkshire.
1854. ‡Waterhouse Nicholas. 5 Rake-lane, Liverpool.
1870. ‡Waters, A. T. H., M.D. 29 Hope-street, Liverpool.
1867. ‡Watson, Rev. Archibald, D.D. The Manse, Dundee.
1855. ‡Watson, Ebenezer. 16 Abercromby-place, Glasgow.
1867. ‡Watson, Frederick Edwin. Thickthorn House, Cringleford, Norwich.
*Watson, Henry Hough, F.C.S. 227 The Folds, Bolton-le-Moors.
Watson, Hewett Cottrell. Thames Ditton, Surrey.
1855. ‡Watson, James, M.D. 152 St. Vincent-street, Glasgow.

Year of Election.

1859. ‡WATSON, JOHN FORBES, M.A., M.D., F.L.S. India Museum, London, S.W.
1863. ‡Watson, Joseph. Bensham Grove, near Gateshead-on-Tyne.
1863. ‡Watson, R. S. 101 Pilgrim-street, Newcastle-on-Tyne.
1867. §Watson, Thomas Donald. 18 A Basinghall-street, London, E.C.
1869. ‡Watt, Robert B. E. Ashby-avenue, Belfast.
1861. ‡Watts, Sir James. Abney Hall, Cheadle, near Manchester.
1846. §Watts, John King, F.R.G.S. St. Ives, Huntingdonshire.
1870. §Watts, William. Oldham Corporation Waterworks, Piethorn, near Rochdale.
1858. ‡Waud, Major E. Manston Hall, near Leeds.
Waud, Rev. S. W., M.A., F.R.A.S., F.C.P.S. Rettenden, near Wickford, Essex.
1862. §WAUGH, Major-General Sir ANDREW SCOTT, R.E., F.R.S., F.R.A.S., F.R.G.S., late Surveyor-General of India, and Superintendent of the Great Trigonometrical Survey. 7 Petersham-terrace, Queen's-gate-gardens, London, W.
1859. ‡Waugh, Edwin. Sager-street, Manchester.
*WAY, J. THOMAS, F.C.S. 9 Russell-road, Kensington, London, S.W.
1869. ‡Way, Samuel James. Adelaide, South Australia.
1871. §Webb, Richard M. 72 Grand Parade, Brighton.
*WEBB, Rev. THOMAS WILLIAM, M.A., F.R.A.S. Hardwick Parsonage, Hay, South Wales.
1866. *WEBB, WILLIAM FREDERICK, F.G.S., F.R.G.S. Newstead Abbey, near Nottingham.
1856. ‡Webster, James. Hatherley Court, Cheltenham.
1859. ‡Webster, John. 42 King-street, Aberdeen.
1862. ‡Webster, John Henry, M.D. Northampton.
1864. §Webster, John. Belvoir-terrace, Sneinton, Nottingham.
WEBSTER, THOMAS, M.A., F.R.S. 2 Pump-court, Temple, London, E.C.
1845. ‡Wedgewood, Hensleigh. 17 Cumberland-terrace, Regent's Park, London, N.W.
1854. ‡Weightman, William Henry. Farn Lea, Seaforth, Liverpool.
1865. ‡Welch, Christopher, M.A. University Club, Pall Mall East, London, S.W.
1867. §Weldon, Walter. 29 The Cedars, Putney, London, S.W.
1850. ‡Wemyss, Alexander Watson, M.D. St. Andrews, N.B.
Wentworth, Frederick W. T. Vernon. Wentworth Castle, near Barnsley, Yorkshire.
1864. *Were, Anthony Berwick. Whitehaven, Cumberland.
1865. ‡WESLEY, WILLIAM HENRY.
1853. ‡West, Alfred. Holderness-road, Hull.
1870. ‡West, Captain E. W. Bombay.
1853. ‡West, Leonard. Summergangs Cottage, Hull.
1853. ‡West, Stephen. Hessle Grange, near Hull.
1851. *WESTERN, Sir T. B., Bart. Felix Hall, Kelvedon, Essex.
1870. §Westgarth, William. 3 Brunswick-gardens, Campden-hill, London, W.
1842. Westhead, Edward. Chorlton-on-Medlock, near Manchester.
Westhead, John. Manchester.
1842. *Westhead, Joshua Proctor Brown. Lea Castle, near Kidderminster.
1857. *Westley, William. 24 Regent-street, London, S.W.
1863. ‡Westmacott, Percy. Whickham, Gateshead, Durham.
1860. §Weston, James Woods. Seedley House, Pendleton, Manchester.
1864. §WESTROPP, W. H. S., M.R.I.A. Lisdoondarna, Co. Clare.

Year of Election.

1860. ‡WESTWOOD, JOHN O., M.A., F.L.S., Professor of Zoology in the University of Oxford. Oxford.
1853. ‡Wheatley, E. B. Cote Wall, Merfield, Yorkshire.
WHEATSTONE, Sir CHARLES, D.C.L., F.R.S., Hon. M.R.I.A., Professor of Experimental Philosophy in King's College, London. 19 Park-crescent, Regent's Park, London, N.W.
1866. ‡Wheatstone, Charles C. 19 Park-crescent, Regent's Park, London.
1847. ‡Wheeler, Edmund, F.R.A.S. 48 Tollington-road, Holloway, London, N.
1853. ‡Whitaker, Charles. Milton Hill, near Hull.
1859. *WHITAKER, WILLIAM, B.A., F.G.S. Geological Survey Office, 28 Jermyn-street, London, S.W.
1866. §White, Charles, F.R.G.S. Barnesfield House, near Dartford, Kent; and 10 Lime-street, London, E.C.
1864. ‡White, Edmund. Victoria Villa, Batheaston, Bath.
1837. ‡WHITE, JAMES, M.P., F.G.S. 14 Chichester-terrace, Kemp Town, Brighton.
White, John. 80 Wilson-street, Glasgow.
1859. ‡WHITE, JOHN FORBES. 16 Bon Accord-square, Aberdeen.
1865. ‡White, Joseph. Regent's-street, Nottingham.
1869. ‡White, Laban. Blandford, Dorset.
1859. ‡White, Thomas Henry. Tandragee, Ireland.
1861. ‡Whitehead, James, M.D. 87 Mosley-street, Manchester.
1858. ‡Whitehead, J. H. Southsyde, Saddleworth.
1861. *Whitehead, John B. Ashday Lea, Rawtenstall, Manchester.
1861. *Whitehead, Peter Ormerod. Belmont, Rawtenstall, Manchester.
1855. *Whitehouse, Wildeman W. O. Roslyn House Hill, Pilgrim-lane, Hampstead, London, N.
Whitehouse, William. 10 Queen-street, Rhyl.
1871. ‡Whitelaw, Alexander. 1 Oakley-terrace, Glasgow.
*WHITESIDE, JAMES, M.A., LL.D., D.C.L., Lord Chief Justice of Ireland. 2 Mountjoy-square, Dublin.
1866. §Whitfield, Samuel. Golden Hillock, Small Heath, Birmingham.
1852. ‡Whitla, Valentine. Beneden, Belfast.
Whitley, Rev. Charles Thomas, M.A., F.R.A.S. Bedlington, Morpeth.
1870. §Whittern, James Sibley. Walgrave, near Coventry.
1857. *WHITTY, JOHN IRWINE, M.A., D.C.L., LL.D., C.E. 94 Baggot-street, Dublin.
1863. *Whitwell, Thomas. Thornaby Iron Works, Stockton-on-Tees.
*WHITWORTH, Sir JOSEPH, Bart., LL.D., D.C.L., F.R.S. The Firs, Manchester; and Stancliffe Hall, Derbyshire.
1870. ‡WHITWORTH, Rev. W. ALLEN, M.A. 185 Islington, Liverpool.
1865. ‡Wiggin, Henry. Metchley Grange, Harbourne, Birmingham.
1860. ‡Wilde, Henry. 2 St. Ann's-place, Manchester.
1852. ‡WILDE, Sir WILLIAM ROBERT, M.D., M.R.I.A. 1 Merrion-square North, Dublin.
1855. ‡Wilkie, John. 24 Blythwood-square, Glasgow.
1857. ‡Wilkinson, George. Monkstown, Ireland.
1861. *Wilkinson, M. A. Eason-, M.D. Greenheys, Manchester.
1859. §Wilkinson, Robert. Lincoln Lodge, Totteridge, Hertfordshire.
1872. §Wilkinson, William. 168 North-street, Brighton.
1869. §Wilks, George Augustus Frederick, M.D. Stanbury, Torquay
*Willert, Paul Ferdinand. Booth-street, Manchester.
1859. ‡Willet, John, C.E. 35 Albyn-place, Aberdeen.
1872. §WILLETT, HENRY. Arnold House, Brighton.
1870. ‡William, G. F. Copley Mount, Springfield, Liverpool.

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1864. *WILLIAMS, Sir FREDERICK M., Bart., M.P., F.G.S. Goonvrea, Perranarworthal, Cornwall.
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1871. ‡Williams, James, M.D. The Mount, Malvern.
1870. §WILLIAMS, JOHN. 10 New Cavendish-street, London, W.
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1869. ‡WILLIAMS, Rev. STEPHEN. Stonyhurst College, Whalley, Blackburn.
1850. *WILLIAMSON, ALEXANDER WILLIAM, Ph.D., F.R.S., F.C.S., Professor of Chemistry, and of Practical Chemistry, University College, London. 12 Fellows-road, Haverstock-hill, London, N.W.
1857. ‡Williamson, Benjamin. Trinity College, Dublin.
1863. ‡Williamson, John. South Shields.
*Williamson, Rev. William, B.D. Datchworth Rectory, Welwyn, Hertfordshire.
WILLIAMSON, WILLIAM C., F.R.S., Professor of Natural History in Owen's College, Manchester. 4 Egerton-road, Fallowfield, Manchester.
WILLIS, Rev. ROBERT, M.A., F.R.S., Jacksonian Professor of Natural and Experimental Philosophy in the University of Cambridge. 23 York-terrace, Regent's Park, London, N.W.; and 5 Park-terrace, Cambridge.
1865. *Willmott, Henry. Hatherley Lawn, Cheltenham.
1857. ‡Willock, Rev. W. N., D.D. Cleenish, Enniskillen, Ireland.
1859. *Wills, Alfred. 43 Queen's Gardens, Bayswater, London, W.
1865. ‡Wills, Arthur W. Edgbaston, Birmingham.
WILLS, W. R. Edgbaston, Birmingham.
1859. §Wilson, Alexander Stephen, C.E. North Kinmundy, Summerhill, by Aberdeen.
1850. ‡Wilson, Dr. Daniel. Toronto, Upper Canada.
1863. ‡Wilson, Frederic R. Alnwick, Northumberland.
1847. *Wilson, Frederick. 73 Newman-street, Oxford-street, London, W.
Wilson, George. 40 Ardwick-green, Manchester.
1863. ‡Wilson, George. Hawick.
1861. ‡Wilson, George Daniel. 24 Ardwick-green, Manchester.
1855. ‡Wilson, Hugh. 75 Glassford-street, Glasgow.
1857. ‡Wilson, James Moncrieff. 9 College-green, Dublin.
1858. *Wilson, John. Seacroft Hall, near Leeds.
*Wilson, John. 32 Bootham, York.
1865. ‡WILSON, JAMES M., M.A. Hillmorton-road, Rugby.
WILSON, Professor JOHN, F.G.S., F.R.S.E. Geological Museum, Jermyn-street, London, S.W.
1847. *Wilson, Rev. Sumner. Preston Candover Vicarage, Micheldever Station.
*Wilson, Thomas, M.A. 2 Hilary-place, Leeds.
1863. *Wilson, Thomas. Shotley Hall, Gateshead, Durham.
1861. ‡Wilson, Thomas Bright. 24 Ardwick-green, Manchester.
1867. ‡Wilson, Rev. William. Free St. Paul's, Dundee.
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1847. *Wilson, William Parkinson, M.A., Professor of Pure and Applied Mathematics in the University of Melbourne.

Year of Election.

1861. ‡WILTSHIRE, Rev. THOMAS, M.A., F.G.S., F.L.S., F.R.A.S. 25 Granville-park, Lewisham, London, S.E.
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1866. *Windley, W. Mapperley Plains, Nottingham.
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*WOLLASTON, THOMAS VERNON, M.A., F.L.S. 1 Barnpark-terrace, Teignmouth.
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1861. *Wood, George B., M.D. 1117 Arch-street, Philadelphia, United States.
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1865. ‡Woodhill, J. C. Pakenham House, Edgbaston, Charlotte-road, Birmingham.
1866. *Woodhouse, John Thomas, C.E., F.G.S. Midland-road, Derby.
1871. §Woodiwis, James. 51 Back George-street, Manchester.
1872. §Woodman, James. 26 Albany-villas, Hove, Sussex.
1869. §Woodman, William Robert, M.D. Alphington-road, Exeter.
*WOODS, EDWARD. 3 Story's Gate, Westminster, London, S.W.
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1870. ‡Woodward, Horace B., F.G.S. Geological Museum, Jermyn-street, London, S.W.
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Woolgar, J. W., F.R.A.S. Lewes, Sussex.
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1856. §Woolley, Thomas Smith, jun. South Collingham, Newark.
1872. §Woolmer, Shirley. 6 Park-crescent, Brighton.
Worcester, The Right Rev. Henry Philpott, D.D., Lord Bishop of, Worcester.
1863. *Worsley, Philip J. 1 Codrington-place, Clifton, Bristol.
1855. *Worthington, Rev. Alfred William, B.A. Old Meeting Parsonage, Mansfield.

Year of Election.

Worthington, Archibald. Whitchurch, Salop.
Worthington, James. Sale Hall, Ashton-on-Mersey.
Worthington, William. Brockhurst Hall, Northwich, Cheshire.
1856. ‡Worthy, George S. 2 Arlington-terrace, Mornington-crescent, Hampstead-road, London, N.W.
1871. §WRIGHT, C. R. A., D.Sc., Lecturer on Chemistry in St. Mary's Hospital Medical School, Paddington, London, W.
1857. ‡Wright, Edward, LL.D. 23 The Boltons, West Brompton, London, S.W.
1861. *Wright, E. Abbot. Castle Park, Frodsham, Cheshire.
1857. ‡WRIGHT, E. PERCEVAL, A.M., M.D., F.L.S., M.R.I.A., Professor of Botany, and Director of the Museum, Dublin University. 5 Trinity College, Dublin.
1866. ‡Wright, G. H. Mapperley, Nottingham.
1865. ‡Wright, J. S. 168 Brearley-street West, Birmingham.
*Wright, Robert Francis. Hinton Blewett, Temple-Cloud, near Bristol.
1855. †WRIGHT, THOMAS, F.S.A. 14 Sydney-street, Brompton, London, S.W.
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1865. †Wrightson, Francis, Ph.D. Ivy House, Kingsnorton.
1871. §Wrightson, Thomson. Norton Hall, Stockton-on-Tees.
1867. †Wunsch, Edward Alfred. 3 Eaton-terrace, Hillhead, Glasgow.
1866. §WYATT, JAMES, F.G.S. Bedford.
Wyld, James, F.R.G.S. Charing Cross, London, W.C.
1863. *Wyley, Andrew. 21 Barker-street, Handsworth, Birmingham.
1867. †Wylie, Andrew. Prinlaws, Fifeshire.
1871. §Wynn, Mrs. William. Cefn, St. Asaph.
1862. ‡WYNNE, ARTHUR BEEVOR, F.G.S., of the Geological Survey of India. Bombay.

*Yarborough, George Cook. Camp's Mount, Doncaster.
1865. †Yates, Edwin. Stonebury, Edgbaston, Birmingham.
Yates, James. Carr House, Rotherham, Yorkshire.
1867. †Yeaman, James. Dundee.
1855. ‡Yeats, John, LL.D., F.R.G.S. Clayton-place, Peckham, London, S.E.
*YORKE, Colonel PHILLIP, F.R.S., F.R.G.S. 89 Eaton-place, Belgrave-square, London, S.W.
Young, James. South Shields.
Young, James. Limefield, West Calder, Midlothian.
Young, John. Taunton, Somersetshire.
Young, John. Hope Villa, Woodhouse-lane, Leeds.
1870. *Young, James, jun. Kelly, Wemyss Bay, Greenock.
Younge, Robert, F.L.S. Greystones, near Sheffield.
*Younge, Robert, M.D. Greystones, near Sheffield.
1868. †Youngs, John. Richmond Hill, Norwich.
1871. †YULE, Colonel HENRY, C.B. East India United Service Club, St. James's-square, London, S.W.

CORRESPONDING MEMBERS.

Year of Election.

1871. HIS IMPERIAL MAJESTY THE EMPEROR OF THE BRAZILS.
1857. M. Antoine d'Abbadie. [U.S.
Louis Agassiz, M.D., Ph.D., Professor of Natural History. Cambridge,
1868. M. D'Avesac, Mem de l'Institut de France. 42 Rue du Bac, Paris.
1866. Captain I. Belavenetz, R.I.N., F.R.I.G.S., M.S.C.M.A., Superintendent of the Compass Observatory, Cronstadt, Russia.
1870. Professor Van Beneden, LL.D. Louvain, Belgium.
1872. Ch. Bergeron, C.E. Lausanne, Switzerland.
1861. Dr. Bergsma, Director of the Magnetic Survey of the Indian Archipelago. Utrecht, Holland.
1857. Professor Dr. T. Bolzani. Kasan, Russia.
1846. M. Boutigny (d'Evreux). Paris.
1868. Professor Broca. Paris.
1864. Dr. H. D. Buys-Ballot, Superintendent of the Royal Meteorological Institute of the Netherlands. Utrecht, Holland.
1861. Dr. Carus. Leipzig.
1864. M. Des Cloizeaux. Paris.
1871. Professor Dr. Colding. Copenhagen.
1870. J. M. Crafts, M.D.
1855. Dr. Ferdinand Cohn. Breslau, Prussia.
1872. Professor M. Croullebois. 18 Rue Sorbonne, Paris.
1866. Geheimrath von Dechen. Bonn.
1862. Wilhelm Delffs, Professor of Chemistry in the University of Heidelberg.
1872. Professor G. Devalque. Liège, Belgium.
1870. Dr. Anton Dohrn. Naples. [Berlin.
1845. Heinrich Dove, Professor of Natural Philosophy in the University of
Professor Dumas. Paris.
Professor Christian Gottfried Ehrenberg, M.D., Secretary of the Royal Academy, Berlin.
1846. Dr. Eisenlohr. Carlsruhe, Baden.
1842. Prof. A. Erman. 122 Friedrichstrasse, Berlin.
1848. Professor Esmark. Christiania.
1861. Professor A. Favre. Geneva.
1872. W. de Fonvielle. Rue des Abbesse, Paris.
1856. Professor E. Frémy. Paris.
1842. M. Frisiani.
1866. Dr. Gaudry, Pres. Geol. Soc. of France. Paris.
1861. Dr. Geinitz, Professor of Mineralogy and Geology. Dresden.
1872. Professor Paul Gervais. Museum de Paris.
1870. Govenor Gilpin. Colorado, United States.
1852. Professor Asa Gray. Cambridge, U.S.
1866. Professor Edward Grube, Ph.D.
1871. Dr. Paul Güssfeldt of the University of Bonn. 33 Meckenheimer-street, Bonn, Prussia.
1862. Dr. D. Bierens de Haan, Member of the Royal Academy of Sciences, Amsterdam. Leiden, Holland.
1872. Professor James Hall. Albany, State of New York.
1864. M. Hébert, Professor of Geology in the Sorbonne, Paris.
Professor Henry. Washington, U.S.
1868. A. Heynsius. Leyden.

Year of Election.

1872. J. E. Hilgard, Assist.-Supt. U.S. Coast Survey. Washington.
1861. Dr. Hochstetter. Vienna.
1842. M. Jacobi, Member of the Imperial Academy of St. Petersburg.
1867. Janssen, Dr. 21 Rue Labat (18° Arrondissement), Paris.
1862. Charles Jessen, Med. et Phil. Dr., Professor of Botany in the University of Greifswald, and Lecturer of Natural History and Librarian at the Royal Agricultural Academy, Eldena, Prussia.
1862. Aug. Kekulé, Professor of Chemistry. Ghent, Belgium.
1866. Dr. Henry Kiepert, Professor of Geography. Berlin.
1861. M. Khanikof. 11 Rue de Condé, Paris.
1868. Professor Karl Koch. Berlin.
1856. Professor A. Kolliker. Wurzburg, Bavaria.
1856. Laurent-Guillaume De Koninck, M.D., Professor of Chemistry Palæontology in the University of Liége, Belgium.
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1872. Georges Lemoine. 19 Rue du Sommerard, Paris.
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1862. Professor P. Merian. Bâle, Switzerland.
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1855. M. l'Abbé Moigno. Paris.
1864. Dr. Arnold Moritz. Tiflis, Russia.
1856. Edouard Morren, Professeur de Botanique à l'Université de Liége, Belgium.
1866. Chevalier C. Negri, President of the Italian Geographical Society, Florence, Italy.
1864. Herr Neumayer. Frankenthal, Bavaria.
1869. Professor H. A. Newton. Yale College, New Haven, United States.
1848. Professor Nilsson. Lund, Sweden.
1856. M. E. Peligot, Memb. de l'Institut, Paris.
1861. Professor Benjamin Pierce. Washington, U.S.
1857. Gustav Plarr. Strasburg.
1870. Professor Felix Plateau. Place du Casino, 15, Gand, Belgium.
M. Quetelet. Brussels.
1868. Professor L. Radlkofer. Professor of Botany in the University of Munich.
1872. Professor Victor von Richter. St. Petersburg.
M. De la Rive. Geneva.
1866. F. Röemer, Ph.D., Professor of Geology and Palæontology in the University of Breslau. Breslau, Prussia.
1850. Professor W. B. Rogers. Boston, U.S.
1857. Baron Herman de Schlagintweit-Sakünlünski. Jaegersburg Castle, near Forchheim, Bavaria.
1857. Professor Robert Schlagintweit. Giessen.
1868. Padre Secchi, Director of the Observatory at Rome.
1872. Professor Carl Semper. Wurtemburg, Bavaria.
1861. M. Werner Siemens. Berlin.
1849. Dr. Siljestrom. Stockholm.
1862. J. A. de Souza, Professor of Physics in the University of Coimbra, Portugal.

Year of Election.

1864. Adolph Steen, Professor of Mathematics, Copenhagen.
1866. Professor Steenstrup. Copenhagen.
1845. Dr. Svanberg. Stockholm.
1871. Dr. Joseph Szabo. Pesth, Hungary.
1870. Professor Tchebichef. Membre de l'Academie de St. Petersburg.
1852. M. Pierre de Tchihatchef, Corresponding Member of the Institut de France. 1 Piazza degli Zuaai, Florence.
1864. Dr. Otto Torell. Prof. of Geology in the University of Lund, Sweden.
1864. Arminius Vámbéry, Professor of Oriental Languages in the University of Pesth, Hungary.
1861. M. de Verneuil. Paris.
1848. M. Le Verrier. Paris.
1868. Professor Vogt. Geneva.
Baron Sartorius von Waltershausen. Göttingen, Hanover.
1842. Professor Wartmann. Geneva.
1868. Dr. H. A. Weddell. Poitiers, France.
1864. Dr. Frederick Welwitsch. Lisbon.
1872. Professor A. Wurtz. Paris.

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Cambridge Philosophical Society.
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Newcastle-upon-Tyne Literary and Philosophical Society.
Nottingham, The Free Library.
Oxford, Ashmolean Society.
——, Radcliffe Observatory.
Plymouth Institution.
Physicians, Royal College of.
Royal Institution.
—— Society.
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Statistical Society.
Stonyhurst College Observatory.
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Trade, Board of (Meteorological Department).
United Service Institution.
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Wales (South) Royal Institution of.
Yorkshire Philosophical Society.
Zoological Society.

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Alten, Lapland. Literary and Philosophical Society.
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Berlin .... Der Kaiserlichen Akedemie der Wissenchaften.
—— .... Royal Academy of Sciences.
Breslau ...... Silesian Patriotic Society.
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Cambridge ....Harvard University Library.
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Washington ..Smithsonian Institution.

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